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U. S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

SALT DESERT SHRUB SYMPOSIUM

CEDAR CITY, UTAH

AUGUST 1-4, 1966

SALT DESERT SHRUB SYMPOSIUM

Table of Contents

	Page
Agenda	1-3
Preface	4
Roster	5-8
Opening Remarks - Dr. Floyd Kinsinger	9-12
Geographic Distribution and Factors Affecting the Distribution of Salt Desert Shrubs in the United States - Dr. F. A. Branson	13-43
Soils of the Salt Desert Shrub Area and their Productive Capabilities - E. A. Naphan	44-68
Erosion Characteristics of Salt Desert Shrub Areas - Norman J. King	69-87
Effects of Surface Soil Treatments on Soil, Water, and Vegetation in Utah's East Desert Area - Dr. George B. Coltharp and Dr. Neil E. West	88-97
The Effect of Season and Intensity of Defoliation on Salt Desert Shrub Range - Dr. C. Wayne Cook	98-100
Wildlife Use of the Salt Desert Shrub Areas of the Great Basin - Norman V. Hancock.	101-112
Use of Wyoming and Montana Salt Desert Shrub Type by Wildlife - Dr. K. E. Severson	113-129
Experience in Improving Salt Desert Shrub Range by Artificial Planting - A. Perry Plummer	130-146
Techniques for Determining the Nutritional Value of Salt Desert Shrub Type for Cattle - A. L. Lesperance	147-156
Nutritional Value of Salt-Desert Shrub Ranges - Dr. C. Wayne Cook	157-159
Plant Ecological Research in Utah's Salt Desert Areas - Dr. Neil E. West	160-169

Table of Contents (continued)

	Page
The Badger Wash Study - O. D. Knipe	170-188
The Management of Whitesage (Eurotia lanata) in Nevada - Dr. Paul T. Tueller	189-202
Establishment and Growth of Halophytes for Grazing Production from Saline Wasteland in Western Australia - C. V. Malcolm	203-217
Economic Importance of Salt Desert Shrub - Dr. Jack F. Hooper	218-225
Sheep Grazing Intensity Studies and Vegetative Changes on Atriplex nuttallii - Dr. Herbert G. Fisser	226-237
Research Needs and Basic Management Considerations on Salt Desert Shrub Ranges - Selar S. Hutchings	238-256
Livestock Management on Salt Desert Shrub Range - Karl G. Parker	257-261
Salt Desert Shrub Range Symposium Summary	262-268
Ecology and Management of Salt Desert Shrub Ranges - a Bibliography compiled by Dr. Neil E. West	269-292

SYMPOSIUM - SALT DESERT SHRUB

August 1-4, 1966
Cedar City, Utah

MONDAY - August 1, 1966

9:00 - 9:15	Introductory Remarks	H. C. Jones Chief, Div. of RPM Utah State Office
9:15 - 9:30	Announcements and Welcome	Lynn Leischman District Manager Cedar City, Utah
9:30 - 9:45	Purpose of Symposium and the Importance of Salt Desert Shrubs to BLM Management Program	Dr. Floyd Kinsinger Range Scientist Range Management Staff Washington, D. C.
9:45	BREAK	
10:15 - 11:00	Geographic Distribution and Factors Affecting the Distribution of Salt Desert Shrubs in the United States.	Dr. F. A. Branson USGS - Denver, Colo.
11:00 - 11:45	Soils of the Salt Desert Shrub Area and their Productive Capabilities.	Ed Naphan Soil Conservation Service Reno, Nevada
11:45	LUNCH	
1:00 - 1:45	Erosion Characteristics of Salt Desert Shrub Areas.	Norman J. King USGS - Denver, Colo.
1:45 - 2:30	Effects of Surface Soil Treatments on Soil, Water, and Vegetation in Utah's East Desert Area.	Dr. George B. Coltharp Utah State University Logan, Utah
2:30	BREAK	
3:00 - 3:45	The Effect of Season and Intensity of Defoliation on Salt Desert Shrub Ranges	Dr. C. Wayne Cook Utah State University Logan, Utah
3:45 - 5:00	Group Discussion of Monday Topics as Related to Range Management.	Moderator: Kay W. Wilkes Range Staff, PSC, BLM Portland, Oregon

TUESDAY - August 2, 1966

8:15 - 9:00	Wildlife Use of the Salt Desert Shrub Areas of the Great Basin.	Norman Hancock Utah F&G Dept. Salt Lake City, Utah
9:00 - 9:45	Use of Wyoming and Montana Salt Desert Shrub Type by Wildlife.	K. E. Severson University of Wyoming Laramie, Wyoming
9:45	BREAK	
10:15 - 11:00	Experience in Improving Salt Desert Shrub Range by Artificial Planting.	A. Perry Plummer Intermountain F&RES Ogden, Utah
11:00 - 11:45	Techniques for Determining the Nutritional Value of Salt Desert Shrub Type for Cattle.	Anthony Lesperance University of Nevada Reno, Nevada
11:45	LUNCH	
1:00 - 1:45	Nutritional Value of Salt Desert Shrub Ranges.	Dr. C. Wayne Cook Utah State Univ. Logan, Utah
1:45 - 2:30	Plant Ecological Research in Utah's Salt Desert Areas.	Dr. Neil E. West Utah State Univ. Logan, Utah
2:30	BREAK	
3:00 - 3:45	The Badger Wash Study	O. D. Knipe Rocky Mtn. F&RES Albuquerque, N. M.
3:45 - 5:00	Group Discussion of Tuesday Topics as Related to Management	Moderator: Joe Townsend BLM, DSC, Denver

WEDNESDAY - August 3, 1966

Field Tour of the Desert Range Experiment Station

THURSDAY - August 4, 1966

8:15 - 9:00	The Management of Whitesage (Eurotia lanata) in Nevada.	Dr. Paul Tueller University of Nevada Reno, Nevada
9:00 - 9:45	Establishment and Growth of Halophytes for Grazing Pro-Duction from Saline Wasteland in Western Australia.	C. V. Malcolm M. Sc. (Agric.) Research Officer Soil Division West. Australia Dept. of Agric. Perth, Australia
9:45	BREAK	
10:15 - 11:00	Economic Importance of Salt Desert Shrub	Dr. Jack Hooper Utah State Univ. Logan, Utah
11:00 - 11:45	Sheep Grazing Intensity Studies and Vegetation Changes on Atriplex nuttallii	Dr. Herb G. Fisser University of Wyo. Laramie, Wyoming
11:45	LUNCH	
1:00 - 1:45	Research Needs and Basic Management Considerations on Salt Desert Shrub Ranges	Selar S. Hutchings Intermountain F&RES Ogden, Utah
1:45 - 2:30	Livestock Management on Salt Desert Shrub Range	Karl G. Parker Utah Extension Service Logan, Utah
2:30	BREAK	
3:00 - 4:00	Group Discussion of Thursday Topics as Related to Management	Moderator: Dr. Floyd E. Kinsinger BLM - Washington, D.C.
4:00	Summary of Entire Symposium	Dr. C. Wayne Cook Utah State University Logan, Utah

PREFACE

The purpose of this symposium was to update the participants in the art and science of managing salt-desert shrub ranges, as well as presenting new concepts and developments. Many questions were raised which will require answers through further research.

The Bureau of Land Management wishes to acknowledge the generosity of each of the men who took time out from their summer schedule to develop such outstanding presentations and to participate in this symposium. Special appreciation is given to the Intermountain Forest and Range Experiment Station personnel for the excellent tour of the Desert Range Experiment Station.

ROSTER

SALT DESERT SHRUB SYMPOSIUM

CEDAR CITY, UTAH
August 1, 1966

Name	Organization
Albrecht, R.	Dept. of Agriculture West Australia
Allison, Eugene	BLM, Denver, Colorado
Applegate, Paul	BLM, SO, Denver, Colorado
Baker, John	BLM, Kanab, Utah
Bleak, Al	ARS, Logan, Utah
Beydler, Jim	BLM, Battle Mountain, Nev.
Branson, Farrel	USGS, Denver, Colorado
Buzan, Martin	BLM, SO, Reno, Nevada
Clark, Ronnie	BLM, Albuquerque, N.M.
Claycomb, Bill	BLM, Montrose, Colorado
Cook, C. Wayne	Utah State Univ., Logan, Utah
Cozakos, Nick	BLM, Richfield, Utah
Cropper, George	BLM, Elko, Nevada
DeLano, Howard R.	BLM, SO, Portland, Oregon
Dimock, Don	BLM, SO, Sacramento, Calif.
Ferris, Ross	BLM, SO, Reno, Nevada
Fisser, Herbert C.	Univ. of Wyoming, Laramie, Wyo.
Ford, Glenn	BLM, Salmon, Idaho
Foreman, Riley E.	BLM, SO, Phoenix, Arizona

Roster - Salt Desert Shrub Symposium

Gomm, F. B.	ARS, Flagstaff, Arizona
Gumert, John	BLM, Las Cruces, N. M.
Hammond, Kelly	BLM, Denver, Colorado
Hancock, Norman	Utah F&G, Salt Lake City, Utah
Harbour, K. Grant	BLM, Grand Junction, Colo.
Heller, Tom	BLM, Denver, Colorado
Hillberry, Dave	BLM, Craig, Colorado
Hirschi, Birrell	BLM, Billings, Montana
Holl, Royal	BLM, Denver, Colorado
Holmgren, Ralph	Intermountain Stn., Ogden, Utah
Hooper, Jack F.	Utah State Univ., Logan, Utah
Hormay, Gus	USFS, Berkeley, California
Hull, A. C. Jr.	ARS, Logan, Utah
Hutchings, Selar	Intermountain Stn., Ogden, Utah
Isaacson, Hal	BLM, Price, Utah
Jacobs, James L.	Forest Service, Ogden, Utah
Jennings, Bob	BLM, Bakersfield, California
Jensen, Morgan	BLM, Cedar City, Utah
Jones, Horace E.	BLM, SO, Salt Lake City, Utah
Keller, Wesley	ARS, Logan, Utah
Kennedy, Arlen P.	BLM, Canon City, Colorado
King, Norman	USGS, Denver, Colorado
King, Terrel,	BLM, Murray, Utah
Kinnamon, Dale H.	BLM, SO, Santa Fe, New Mexico

Roster - Salt Desert Shrub Symposium

Kinsinger, Floyd E.	BLM, Washington, D. C.
Knipe, O. D.	USFS, Albuquerque, N.M.
Larson, Carl	BLM, Rawlins, Wyoming
Leonard, Paul	BLM, Roswell, New Mexico
Lesperance, A.	Univ. of Nevada, Reno, Nevada
Luscher, Bill	BLM, Denver, Colorado
McCrillis, Carl	BLM, Portland, Oregon
McKell, Cyrus	Univ. of Calif., Riverside, Calif.
McKendrick, Jay T.	Univ. of Idaho, Moscow, Idaho
Malcolm, Clive	Dept. of Agr., West Australia
Malencik, Bill	BLM, SO, Reno, Nevada
Mason, Lamar R.	SCS, Salt Lake City, Utah
Melin, Ken	USGS, Denver, Colorado
Moore, Russell	Utah State Univ., Logan, Utah
Naphan, Edmund	SCS, Reno, Nevada
Nodine, Gene	BLM, Las Vegas, Nevada
Nord, E. C.	USFS, Berkeley, California
Ogurek, Vince	BLM, Phoenix, Arizona
Orr, Davis	BLM, Fillmore, Utah
Oldroyd, Larry	BLM, Vernal, Utah
Palmer, Ernest	BLM, Portland, Oregon
Parker, Karl G.	Utah State Univ., Logan, Utah
Pearson, Marvin W.	BLM, SO, Denver, Colorado
Pendleton, Donald L.	BLM, Portland, Oregon
Plummer, Perry	Intermountain Stn., Ogden, Utah

Roster - Salt Desert Shrub Symposium

Rathner, Harry B.	BLM, Worland, Wyoming
Satterfield, Ken	BLM, Winnemucca, Nevada
Seibert, Donald	BLM, Glenwood Springs, Colo.
Smith, S. M.	Dept. of Agric., West Australia
Sweet, LeRoy	BLM, Denver, Colorado
Templeton, Billy	BLM, Riverside, California
Townsend, Joe	BLM, Denver, Colorado
Tueller, Paul T.	Univ. of Nevada, Reno, Nevada
Vosler, L. Christian	BLM, Denver, Colorado
Wein, Ross	Utah State Univ., Logan, Utah
West, Neil	Utah State Univ., Logan, Utah
Whiting, Jim	BLM, Rock Springs, Wyoming
Wilde, Wayne W.	BLM, Carson City, Nevada
Wilkes, Kay	BLM, Portland, Oregon
Wood, Arnold C.	BLM, Ely, Nevada
Wood, Douglas	BLM, Monticello, Utah
Woodbury, Marvin	BLM, St. George, Utah
Workman, John	Utah State Univ., Logan, Utah.

Opening Remarks
Salt Desert Shrub Sumposium
Floyd E. Kinsinger

Greetings from Washington, Gentlemen! Because of travel restrictions imposed by the airline strike Mr. Smith, Mr. Turcott, or Dr. Fulcher, listed on your program, were not able to come to the meeting. So I am the fourth string substitute in the ball game. I know how much they had looked forward to coming because we have all anticipated that this would be an excellent meeting and I know they regret not being here. It is an honor for me to be here, representing our Washington Office.

I have been privileged to attend several symposia: Cheatgrass Management Symposium held in Vale, Oregon, and the Crested Wheatgrass Management Symposium in Burns, Oregon. These symposia were started several years ago by joint efforts of our Oregon BLM Office and the ARS. They developed into such excellent meetings that we believed it was desirable to expand them Bureau-wide and include other agency personnel. These meetings of the past set high standards which we hope to continue. We plan to conduct a symposium annually if possible wherein we select a limited topic and study and discuss it thoroughly. We try to get the best brains available to meet with us, to provide us the information, facts, and data that we can put into practice as the responsible land managing agent.

These meetings are expensive for BLM. We have here approximately 50 people, some have travelled long distances. But we reap large

benefits from such a discussion as this, and most importantly, the land receives increased attention and management from the facts we learn. However, it is most important that we question these knowledgeable speakers when doubt exists, that we discuss points of interest needing clarification, and that we share our experiences and problems, as the land manager, with these researchers. Our benefit and application to better land management is in direct proportion to the amount of discussion we generate.

These speakers on the program will not tell you how to manage. They will give us information which we must interpret and apply. Keep them honest and practical. If they give us impractical information or of doubtful application to public lands, challenge them. They can learn from us too.

Textbooks tell us that the Salt Desert Shrub encompasses about 40 million acres--almost all on BLM land. This is a vast, hot, dry, foreboding land. It has not received the attention it should from research or managing agencies. Frankly, I do not think we know how to manage salt desert shrub. And in many cases we do not apply the principles we do know. For example, it has long been recognized as "winter range." Yet we license grazing use year-long or permit late spring grazing on "winter range." I have seen stands of whitesage converted to halogeton in a few short years by improper management. I have seen areas of shadscale and greasewood that we attempted to plow and seed.

What do we know about the salt desert? What is the climate? We know it's harsh and arid. What do we know about soils and hydrology? Does it have potential for wildlife habitat? What is the response of forage species to grazing use? If we ask ourselves these questions, I think we have to admit we know very little about this area.

But knowledge about the salt desert is beginning to accumulate at an ever-increasing rate. I believe it is a good sign when we are man enough to admit we do not know and turn to the source of knowledge. It is a good sign when research and management can get together, as we are here, and exchange ideas.

We in BLM have an opportunity not afforded very many others -- management of the public domain. This is a charge entrusted only to a select few, many of whom are in this audience. It requires no particular talent to manage fertile irrigated land and, all due respects to my Forest Service friends, they have better environments to work in and manage than BLM. We got the left-over land that no one else wanted. What a challenging opportunity to use our craftiest wiles, judgment, and knowledge to manage these rejected lands! It takes a special breed of man.

Knowledge is accumulating. For instance, we are learning that plants of the salt desert respond slowly to climate or use. Therefore, any grazing system, such as rest rotation, will have to provide more opportunity for plant recovery. I reject the philosophy I often hear,

"why manage it, we can't hurt it." How will we know until we pit our management skills against this salt desert type.

As a matter of fact, under the new PPBS system we may not be able to justify any investment in this vast area except management. Under this system, projects must be justified and a favorable cost-benefit ratio must result. In the salt desert type, perhaps the only salvation is management.

We have a lot of talent assembled here. I want to emphasize again that discussion and questions concerning the presented papers are important. We are looking forward to a very successful and beneficial symposium.

Thank you.

Geographic distribution and factors affecting the distribution of salt desert shrubs in the United States

F. A. Branson, Botanist
U.S. Geological Survey
Denver, Colorado

INTRODUCTION

The phrase "salt desert shrub" has been interpreted in a variety of ways by different authors. The vegetation commonly found below 5,500 feet in the Great Basin and eastern Utah with extensions into many other States has been referred to as a "formation", a "desert", a "biome", a "zone", a "type", an "area", a "province", and possibly by other names. For the most part, these names represent different points of view rather than confusion. Admittedly, most classification systems are artificial but they are helpful to anyone who tries to understand complex natural phenomena. Before reviewing the classification systems that have been applied to salt desert shrub vegetation, a brief evaluation of the meager information available on the origin of Great Basin desert species may be informative.

Origin of Salt Desert Shrub Vegetation

In terms of geologic time, the deserts east of the Sierra and Cascade Mountains are of relatively recent origin. During epochs as recent as Pliocene (less than 10 million years before present), Axelrod and Ting (1960) propose that Sierran forests, requiring 20 to 25 inches more precipitation than now occurs, occupied lowlands of the western Great Basin. The Sierra-Nevada Mountains rose 3,000 feet in early Pleistocene, another 3,000 feet by mid-Pleistocene and another 1,000 to 1,500 feet by the end of Sangamon time (ca 70,000 years before present). The increased aridity inland caused by the rise of Pacific Coast mountain ranges resulted in the change from mesophytic forests to drought tolerant shrubs.

Early Pleistocene (ca 1,000,000 years before present) was moist and cool in the Great Basin. From the fossils of herbivores such as bison, camel, elephant, and horse it is inferred that grasslands were widespread in the Great Basin in early Pleistocene (Axelrod, 1950). Conifers and woodlands were found at lower altitudes than today and deserts were much restricted. The present vegetation developed from Tertiary floras which Axelrod (1950) groups as Arcto-Tertiary and Madro-Tertiary. The genera Chrysopsis, Chrysothamnus, Eriogonum, Grayia, Salvia, Sphaeralcea, Stenopteris, and Tetradymia are thought to have originated in the neotropics because their relatives now extend into the tropics. Some of the many genera that are thought to have northern origins because they occur both in Eurasia and North America include : Artemisia, Atriplex, Eurotia, Suaeda, Koeleria, Agropyron, Salicornia, Elymus, Hordeum, and Festuca.

Classifications of Salt Desert Shrub Communities

One of the earliest and most complete classifications is that of H. L. Shantz (1924, 1925; table 1). His groupings of Northern Desert Shrub Formation and Salt Desert Shrub (Greasewood) Formation affect our thinking today, but the variety of concepts applied in more recent community classifications indicates that there is still a search for the ideal system or concept. The criterion used by Shantz for the two major communities appears to have been upland sites versus those sites receiving "run in" moisture. More recent publications have shifted many of the communities from one grouping to the other, resulting in a regrouping of all salt-tolerant species into the Salt Desert Shrub (Greasewood) Formation and ignoring the runoff-runin moisture criterion of Shantz. Hutchings and Stewart (1953) list only big and black sagebrushes in their "Sagebrush-grass Formation" and most of the other common shrubs are assigned to the Salt Desert Shrub Formation. The Clemensian terminology of Shantz is of interest. He felt that winterfat was a successional or seral community because it sometimes replaced shadscale. This is one of Shantz's views that now seems erroneous. For example, winterfat communities are now being invaded by Halogeton glomeratus (Eckert, 1954); and Fautin (1946) proposed that much of the type had been replaced by little rabbitbrush (Chrysothamnus stenophyllus). The Clemensian terminology (Weaver and Clements, 1938) occurs infrequently in recent papers.

Table 1.--Classification system for vegetation of the Great Basin proposed by H. L. Shantz (1925).

Northern Desert Shrub Formation

- Sagebrush association (*Artemisia tridentata*)
- Small sagebrush association (*Artemisia nova*)
- Little rabbitbrush associes (*Chrysothamnus puberulus*)
- Shadscale association (*Atriplex confertifolia*)
- Winterfat associes (*Eurotia lanata*)
- Hop-sage and Coleogyne association (*Grayia spinosa* and *Coleogyne ramosissima*)
- Bud sagebrush association (*Artemisia spinescens*)
- Mat saltbush association (*Atriplex corrugata*)
- Gray molly association (*Kochia vestita*)

Salt Desert Shrub (Greasewood Formation)

- Greasewood association (*Sarcobatus vermiculatus*)
- Greasewood shadscale association (*S. vermiculatus* and *Atriplex confertifolia*)
- Seepweed association (*Dondia torreyana*)
- Pickleweed association (*Alburolfea occidentalis*)
- Samphire association (*Salicornia utahensis* and *S. rubra*)
- Saltgrass associes (*Distichlis stricta*)
- Alkali sacaton associes (*Sporobolus airoides*)
- Rabbitbrush associes (*Chrysothamnus graveolens*)

Shreve (1942), in his Botanical Review article on North American deserts, used both the zonation concept and edaphic factors in his ordination of plant communities (Table 2). However, Shreve questioned the view that there are "fundamental units" of vegetation and recognized that even when multiple criteria are used it is difficult to classify vegetation types. Shreve cites the work by Kearney and collaborators (1914) and lists their values for salt tolerances of the species present near the Great Salt Lake. Shreve's presentation is a general description, but the classification shown in table 2 may be derived from it.

Fautin (1946) proposed a bio-ecological classification with the "biome" (Table 3) being the equivalent of a "biotic formation." The author objected to the "Sagebrush Climax" of Clements (Weaver and Clements, 1938) because other climax communities in southwestern Utah seemed of importance equal to that of sagebrush. In fairness to Clements, it should be noted that Clements referred to the type as the Sagebrush Formation (Atriplex-Artemisia) which indicates some recognition of the importance of species of the two most widespread genera. The classification of Fautin also shows disagreement with Shantz in the rank of winterfat as a climax community.

Table 2.--Shreve's (1942) classification of Great Basin Desert vegetation.

Great Basin Desert

Juniperus utahensis (6,000 to 7,000 feet)

Artemisia tridentata (upper belt)

Atriplex confertifolia (lower belt)

Kochia vestita

Sarcobatus vermiculatus

Distichlis stricta-*Sporobolus airoides*

Salicornia rubra, *S. utahensis*, *Alleurolfea occidentalis*

Coleogyne ramosissima

Table 3.--Bio-ecologic classification of Great Basin vegetation by Fautin (1946).

Pinon-Juniper Biome

Northern Desert Shrub Biome

- Shadscale Community
- Tetradymia Community
- Greasewood Community
- Winterfat Community
- Black Sage Community
- Pickleweed Community
- Little Rabbitbrush Associes
- Sagebrush Community

Southern Desert Shrub Biome

A classification adopted by many recent authors is that by Billings (1949). (See Table 4.) Billings, in contrast to systems used previously, applied to the Great Basin flora the zonation concept as used by Daubenmire (1943) for flora of the Rocky Mountains. An interpretation of Billings' article shows the listing of two major zones: (1) Sagebrush is the upper, wetter one, and (2) Shadscale is the lower, dryer one. He views all the communities within the shadscale zone as minor edaphic climaxes forming a mosaic. The quantitative data in the paper by Billings is on Nevada vegetation with references to the work by Fautin (1946) for information on Utah Great Basin vegetation.

Proposed in Table 5 is a new vegetation classification based on maximum salt tolerances of communities and on the capacity of one group, the Salt Marsh Zone, to exist partially submerged in water during all or part of the year. The data are presented in atmospheres osmotic stress at field capacity because of the ease of interpreting these values in terms of plant physiology. Maximum values for each community were obtained from published reports and from unpublished data obtained by the author. The osmotic stress at 15 atmospheres soil-moisture stress, the suction force sometimes considered to be the permanent wilting point, can be obtained by multiplying the values shown by two except for the Salt Marsh Zone. Osmotic stress at saturation is shown for Salt Marsh Zone communities because these habitats usually have moist soils. To obtain total soil moisture stress for communities other than those of the Salt Marsh Zone, the stress caused by soil-particle size (physical or matric stress) would be added to values for osmotic stress.

Table 4.--The zonation concept applied to Great Basin vegetation by Billings (1949).

Sagebrush zone

Shadscale zone

Edaphic climaxes in zone:

Greasewood

Greasewood-shadscale

Pickleweed

Winterfat

On dune sands:

Dalea polyadenia-Tetradynia glabrata

Chrysothamnus stenophyllus

Table 5.--A new classification being proposed here for the Intermountain shrub region. Maximum tolerances to osmotic stress and water relationships are criteria used in this classification.

OSMOTIC STRESS AT FIELD CAPACITY ATMOSPHERES	
	Juniper-pinyon Zone
	Sagebrush Zone
0.01	Little rabbitbrush community (Chrysothamnus viscidiflorus)
0.1	Big sagebrush community (Artemisia tridentata)
0.2	Black sagebrush community (Artemisia nova)
	Salt Desert Shrub Zone
	Bud sagebrush community (Artemisia spinescens)
0.6	Winterfat community (Eurotia lanata)
2.2	Shadscale community (Atriplex confertifolia)
3.2	Desert molly community (Kochia americana)
5.0	Greasewood community (Sarcobatus vermiculatus)
5.0	Nuttall saltbush community (Atriplex nuttallii)
	Mat saltbush community (Atriplex corrugata)
OSMOTIC STRESS AT SATURATION ATMOSPHERES	
	Salt Marsh Zone
1.5	Rabbitbrush community (Chrysothamnus nauseosus)
2.8	Alkali sacaton community (Sporobolus airoides)
16	Saltgrass community (Distichlis stricta)
23	Seepweed community (Suaeda torreyana)
35	Glasswort community (Salicornia utahensis and Situbra)
35	Pickleweed community (Allenrolfea occidentalis)
50	Algae
75	Fungi

For all the communities in the Salt Marsh zone except rabbitbrush and alkali sacaton, the osmotic stress alone exceeded the 15 atmospheres sometimes used to represent the permanent wilting stress. Under conditions that are too salty for vascular plants in salt marshes of Death Valley, Hunt (1966) found algae surviving osmotic stresses of 50 atmospheres and fungi on areas with as much as 75 atmospheres.

The zonation concept seems suitable for the kinds of vegetation described for two reasons. There is altitudinal zonation of vegetation in the areas that results from increasing precipitation and decreasing temperatures with an increase in altitude. There are also zones of vegetation that represent responses to increasing concentrations of soil salts as one proceeds from higher to lower altitudes. These two factors, altitudinal effects and salinity effects, generally parallel each other as one descends into each of the many closed basins within the Great Basin. In addition to increased aridity and salinity with descent into each basin, soil-particle sizes tend to become smaller as one approaches the playas, resulting in higher soil moisture stresses. Local areas, such as those occupied by wind-blown sand and certain geologic materials, provide exceptions to this generalization.

The salt marshes that occupy some playa bottoms are presented in table 1 as a separate zone and it should be noted further that these are not true desert plant communities in the sense that they are limited to deserts. Salt marshes are also common in moist climates (Weaver and Clements, 1938, p. 227) and are even more abundant along seacoasts (Chapman, 1960). Many of the genera and some of the species are the same over much of the world.

Although the maximum osmotic stress values shown in table 5 appear to provide a rational ordination of plant communities, caution must be applied when using plants as precise indicators of salinity. Gates, Stoddart, and Cook (1956) found that although mean values differed significantly between communities, there were overlapping salt tolerances for the five salt desert shrub communities studied. However, classification of plant communities on the basis of maximum tolerances is in agreement with the statement by Daubenmire (1948): "In general, the greater the salt tolerance of a species, the wider the range of salinity of the soils on which it grows, i.e., the degree of maximal salt tolerance is more definite than the minimal."

Distribution of Salt Desert Shrub Communities

The Great Basin Desert as mapped by Shreve (1942) extends far beyond the Great Basin physiographic province into the Columbia Plateau and the upper Colorado River basin. More information now exists than was available to Shreve, and the boundaries could be extended to include a larger portion of Wyoming, parts of Montana and a larger portion of New Mexico and still comply with Shreve's criteria which emphasized life forms, structure, and floristics. Shreve's map indicates the extent of plant communities listed in table 5. Shreve characterizes the Great Basin Desert as being ". . .largely above 4,000 feet and has frequent periods of freezing temperatures of a week or more in duration." This contrasts with the Mojave Desert to the south which is largely below 4,500 feet and is warmer and dryer. A major criterion used by Shreve to separate the two deserts is the presence of creosote bush (Larrea tridentata) in the Mojave Desert.

Undoubtedly the best vegetation map of the United States available at present is the one by Küchler (1964). Shown in figure 1 are tracings from Küchler's map with the addition of some salt desert shrub areas in Montana and Wyoming. The cross-hatched area represents the types where big sagebrush is dominant and has a planimetered area of 143 million acres, a larger area than some of the estimates that are in print (U.S. Dept. Agr., 1936). The extent of sagebrush types is shown because salt desert shrubs, at least in minor amounts, occur throughout most of the area occupied by big sagebrush.

The solid black area representing the extent of areas dominated by salt desert shrubs has a planimetered area of 38 million acres which is somewhat less than many of the estimates in the literature (Hutchings and Stewart, 1953). The three small areas in Montana and one in northeastern Wyoming are not shown on Küchler's map. Although small, these areas are important because the sparse plant cover and fine-textured soils give rise to high sediment yields and, in some areas, spectacular erosion. An example of the latter is the Willow Creek valley in northeastern Montana which has an eroded trench about 20 feet deep and 30 miles long. Much of the trenching has occurred during the life of residents of the area. The basin has been thoroughly treated by the Bureau of Land Management to control erosion.

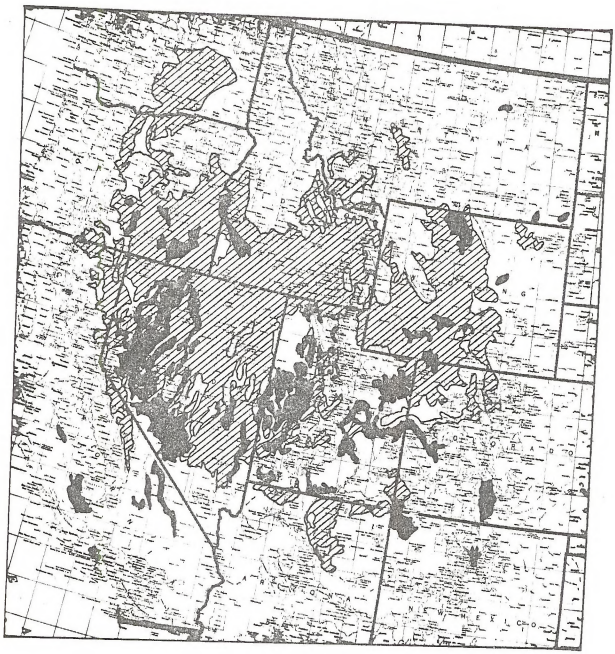

Figure 1.--Distribution of the saltbush-greasewood type (in solid black) and the sagebrush type (cross-hatched). (Revised from Küchler, 1964.)

Geographic Distribution of Salt Desert Shrub Species

The distribution of salt desert shrub species is far greater than the areas dominated by these plants (compare figure 1 with figure 2). The wide latitudinal and longitudinal ranges of these species indicate that some factor or factors other than climate determine areas in which salt desert shrubs are dominants. Edaphic factors seem to determine the presence of pure stands of salt desert shrubs but, as pointed out earlier, many species have overlapping tolerances for soil characteristics that have been measured. This view of climatic effects is not in full agreement with that of Billings (1949) who states that "The shadscale zone is characterized by a much dryer climate than the sagebrush zone and lies between the sagebrush and creosotebush zones." The complexity of the problem 'Why do plants grow where they do?" has been thoroughly explored by Billings (1952). It is hazardous and possibly erroneous to attempt to over-simplify the cause and effect relationships responsible for plant species distribution.

Throughout the distributions shown, salt desert shrubs exert dominance locally, but usually on areas too small to appear even on large scale vegetation maps. However, extensive and nearly pure stands are largely restricted to the States of Nevada and Utah. The most widely distributed of the salt desert shrubs is winterfat. The wide ecologic amplitude of winterfat is demonstrated by both the extensive geographic area in which it occurs and the variety of species with which it is associated. Altitudinal range of winterfat is from about 2,000 feet to 10,000 feet.

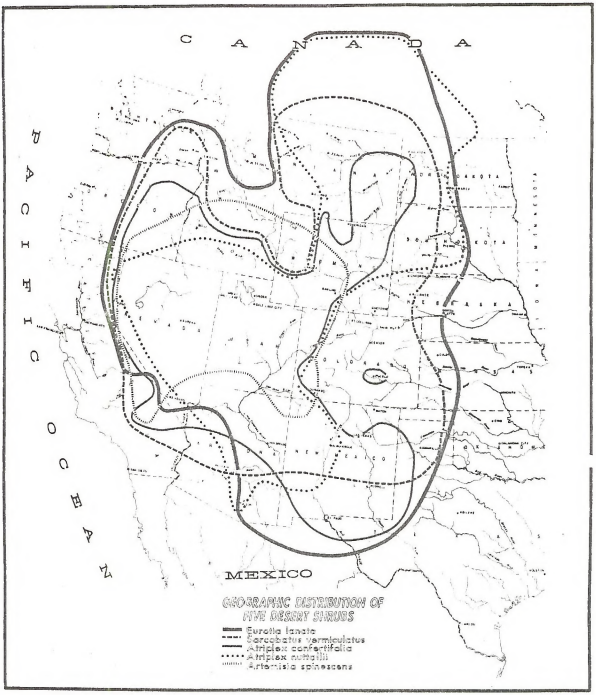

Figure 2.--The approximate geographic distribution of winterfat (Eurotia lanata), greasewood (Sarcobatus vermiculatus), shadscale (Atriplex confertifolia), nuttall saltbush (A. nuttallii), and bud sagebrush (Artemisia spinescens).

Greasewood, nuttall saltbush, and shadscale are almost as widely distributed as winterfat. There is no apparent reason for the disjunct distribution of shadscale in western Colorado, where it is common, and the isolated area of shadscale in southeastern Colorado.

There are a number of salt tolerant shrubs in the Mojave, Sonoran, and Chihuahuan Deserts, but these have not been included in the Salt Desert Shrub Zone of the Great Basin desert. Although absent or rare in the Great Basin desert, they merit a brief mention here. Cattle spinach (Atriplex polycarpa) is one of the most important saltbushes in the Sonoran and Mojave deserts. Soils occupied by it are usually coarse to medium textured, not high in salts, and are generally considered irrigable. Desert holly (Atriplex hymenalytra) is one of the most drought tolerant plants of the southwest deserts. In Death Valley (Hunt, 1966) it occupies ". . .the lowest, smoothest, saltiest, and hottest parts of the gravel fans."

One of the most widely distributed saltbushes is four-wing saltbush (Atriplex canescens). Although its latitudinal range is from Montana to Mexico it is seldom found in pure stands. Four-winged saltbush usually occurs on sandy soils.

Some causative factors for the presence

of salt desert shrub communities

Shown on figure 3 are plant communities as found on different strata of Bearpaw Shale exposed on a hill in Montana. The data shown are hits per 100 pins as measured by the all contacts point-quadrat method at 2-inch intervals over a distance of 1,080 feet from the top to the bottom of the hill. The Curtiss (1956) continuum concept or the Whittaker (1953) population pattern concept could be applied to the data, but the classical concept (Hanson and Churchill, 1961) which recognizes dominance and names communities seems preferable. Nuttall saltbush communities are present on the dry, exposed hilltop and again on fine-textured alluvium at the base of the hill. Big sagebrush types occur adjacent to the two nuttall saltbush types. Centrally located on the hill in a highly gypsiferous soil is a buckwheat (Eriogonum multiceps) community. Two species showing wide ecologic amplitude are western wheatgrass (Agropyron smithii) and knotweed (Polygonum aviculare). It is probable that propagules from species of each plant community have reached all the habitats on the hill almost annually, but the communities remain distinct. This statement leads to the very difficult question, "Why are these adjacent plant communities different?"

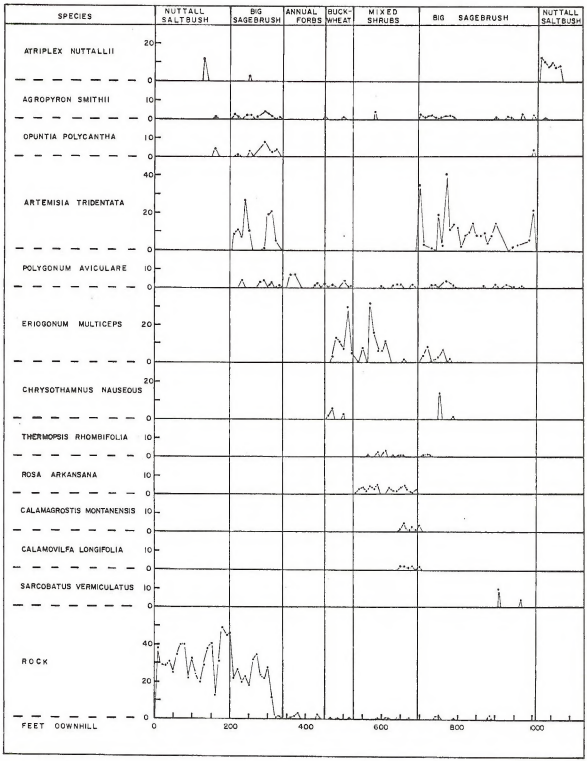

Figure 3.--Plant communities on a hill with different strata of Bearpaw Shale exposed. The data are hits per 100 pins, as determined by the all contacts point-quadrat method with pins at two-inch intervals.

This report seems to me to require some brevity, thus only the highlights of figure 4 will be discussed. The moisture use index (differences between maximum and minimum storage calculated in cubic centimeters) is low for the two nuttall saltbush communities, and maximum total soil-moisture stress reached near the depth to which roots penetrated was greatest in these two communities. These data show that nuttall saltbush is the most drought tolerant of the species present on the sampling sites. Centrifuge moisture equivalents, representing moisture storage possible at field capacity to the depth of rooting, are similar to, but exceed, the moisture use index. These are expected results because field capacity percentages were seldom reached in the soils studied. pH has no apparent effect on the plant community differences. The high pH at the top of the hill is caused by an outcrop of limestone, indicated as rock at the bottom of figure 3. Total soluble cations are highest in soils of the two nuttall saltbush communities indicating that this species is salt tolerant as well as drought tolerant. As has been found in many other studies (Gates, Stoddart, and Cook, 1956; Fireman and Hayward, 1952), big sagebrush occupied sites that contained low quantities of salts.

The soils of the nuttall saltbush communities were sodic and, surprisingly, the two big sagebrush communities were also present on soils containing high soluble sodium percentages. Gates, Stoddart, and Cook (1951) found big sagebrush on soils with low sodium values. Soils of the buckwheat type had low sodium contents, but relatively high quantities of salts. This provides evidence that the primary cation in the soils occupied by buckwheat is calcium and additional evidence is provided by thepresence of gypsum crystals, selenite, on the soil surface.

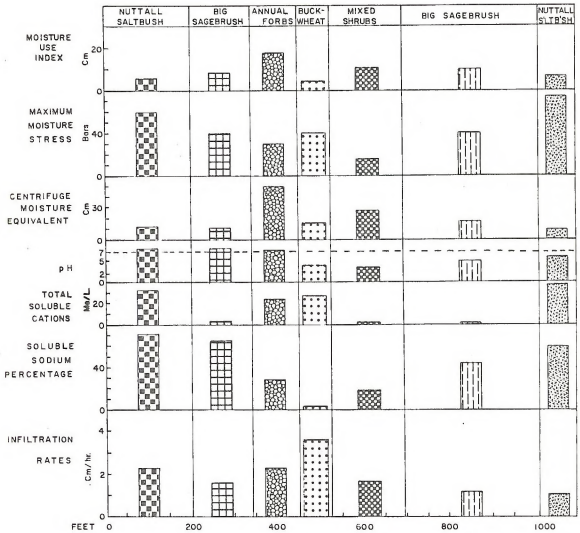

Figure 4.--Physical and chemical characteristics of soils for the seven plant communities shown in figure 3.

Infiltration rates as measured by a portable infiltrometer (McQueen, 1963) gave variable results that do not appear directly related to soil moisture measurements. All rates were low and only one, the buckwheat, had a rate exceeding one inch (2.54 centimeters) per hour. The infiltrometer has measured rates of up to nearly 14 inches per hour on sandy soils in California (Branson, Miller, and McQueen, 1961).

From these data it is concluded that soil-moisture relationships are the primary cause of the different plant communities. Quantities of soil salts also appear to be important as a cause of community differences, but it may be that the major effects of salts is their osmotic stress contribution to total soil-moisture stress. The only community of the seven that may be present as a result of kinds of soil chemicals is the buckwheat type which occurred on gypsiferous soil.

Minimum and maximum total soil-moisture stress for seven plant communities in the Willow Creek basin in Montana are shown in figure 5. Total soil moisture stress was measured by the method developed by McQueen and Miller (in press) which permits measurement of stresses of 0 to 1,500 bars (one bar = .99 atmosphere) in field gravimetric samples. Total stresses reached nearly 800 bars in nuttall saltbush soil in the fall. The vertical dashed lines shown for each community represent the average (six sampling periods during the year) total soil-moisture stress at the depth where plant roots become few in number. The fact that the curves for all soil moisture measurements made tend to come together at this characteristic depth in the communities must have meaning when related to the kinds of plants growing on the different soils. One interpretation is that the average total soil-moisture stress at this depth represents the maximum stress to which the plants present on each site can remove moisture from the soil. Stresses greater than this average are attributable to water removed from the soils by solar energy. Of the communities shown, nuttall saltbush had the smallest quantity of plant material to intercept solar radiation and the highest moisture stress near the soil surface, whereas the quantity of plant material was greatest in the silver sagebrush community which had the lowest total soil moisture stress at the average rooting depth. Average total soil moisture stress was more than 90 bars for the nuttall saltbush soil and 35 bars for the silver sagebrush soil. These data were derived from a new calibration of filter paper moisture as a measure of total soil moisture stress and differ somewhat from the values shown in figure 4. Analysis of variance for these data shows that differences between the sevel communities are highly significant.

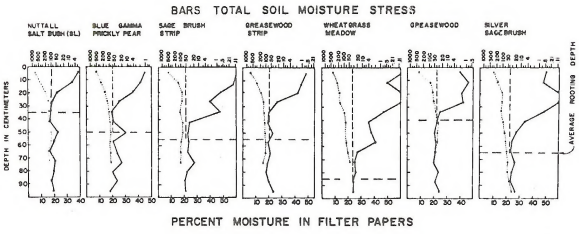

Figure 5.--Minimum total soil moisture stress for the season is represented by the solid line, maximum stress by the dotted line, and average maximum stress attained by each community is shown by the vertical dashed line. The data are for 7 plant communities on Bearpaw Shale in northeastern Montana.

The data on average total soil moisture stress can be more easily compared in figure 6 than in figure 5. The range of values for the 14 plant communities is from more than 90 bars for nuttall saltbush to only 19 bars for the mixed shrub community. To one familiar with the habitat requirements of the species shown, the grouping appears logical. One possible exception is the low drought tolerance indicated for the greasewood-western wheatgrass type. A possible explanation of this seeming discrepancy is that soil moisture sampling was to a depth of three feet, but greasewood is known to have roots extending to more than 19 feet in the area studied.

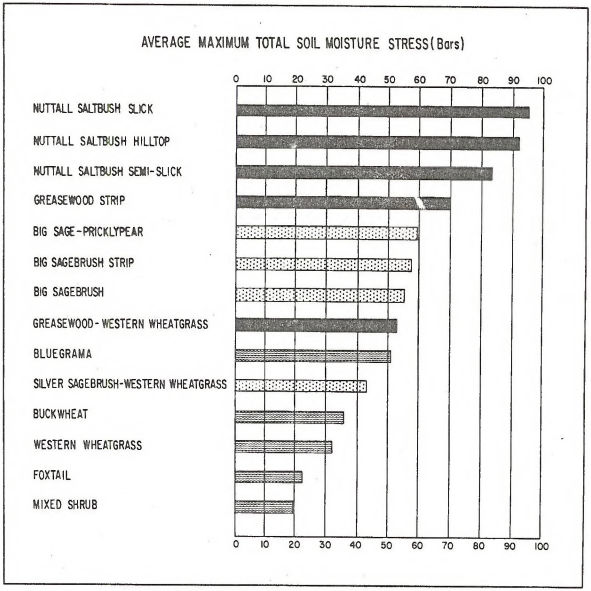

Figure 6.--Average total soil moisture stress at average rooting depth in 14 plant communities in the Willow Creek area, Montana. Black bars indicate salt desert shrubs, stippled bars nonhalophytic northern desert shrubs, and wavy lines indicate types not considered to be northern desert shrub communities.

Measurements of osmotic stress do not show that halophytes occupy only soils high in salts (fig. 7). Data shown in figure 7 were obtained as a part of a study of mechanical treatment effects (Branson, Miller, and McQueen, 1966) in Montana, Wyoming, Utah, Colorado, Arizona, and New Mexico. Although the criterion for site selection was the presence of mechanically treated land, a variety of vegetation types were included in the 58 areas sampled. Barren ground and nuttall saltbush occupied the sites highest in salts, but other halophytic types such as nuttall saltbush-blue grama, shadscale, spiny horse-brush, and winterfat, were the dominants on soils relatively low in salts. Although the results are not conclusive, the data in figures 6 and 7 indicate that total soil-moisture stress provides a more precise measure of drought tolerance than does osmotic stress alone. The data also indicate that the capacity of halophytes to tolerate high total soil-moisture stress may be more informative in attempts to explain dominance by these plants than soil-salt content alone. If ecological literature were not already too cluttered with terminology, the term "xerohalophytes" could be proposed for most salt desert shrub species to indicate that either or both xeric or halic soils may determine their presence on a site.

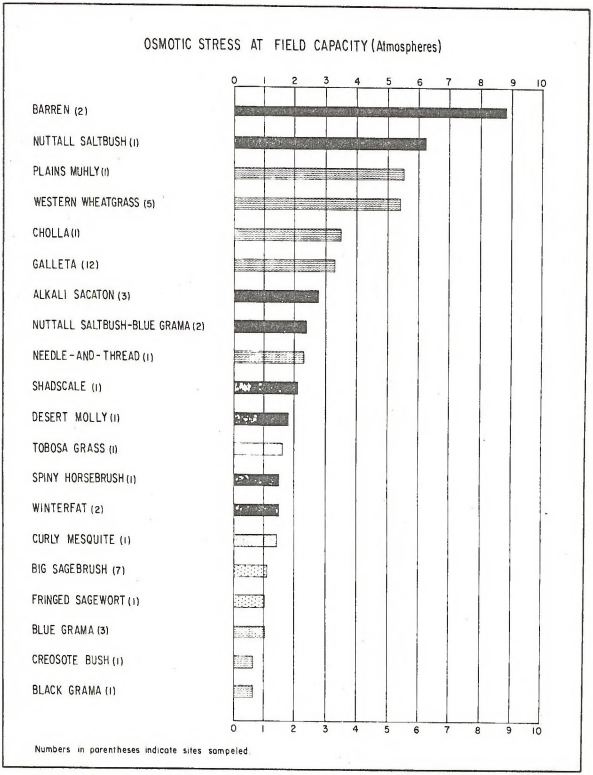

Figure 7.--Osmotic stress caused by soil salts in 20 vegetation types in six western states. Sites sampled varied from 12 to one per type with a total of 58 sites sampled. Black bars indicate salt desert shrubs.

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SOILS OF THE SALT DESERT SHRUB AREA AND THEIR PRODUCTIVE CAPABILITIES

E. A. NAPHAN
Salt Desert Shrub Symposium

The subject matter of this symposium, as you may appreciate, is not a simple one. The area involved is of considerable extent, and is characterized by a rather adverse climate; a complex physiography and geologic history; and a diverse occurrence of plants and soils.

In spite of the name assigned to characterize the broad kind of vegetation occurring in the area, we find that the soils are not all salty, and that their hydrologic characteristics may often be responsible for the typical associated vegetation. The soils that I will be discussing today may therefore be considered as those that have one or both of the following: (1) An excessive quantity of soluble salts throughout or in some part of the soil profile; and (2) Critical limitations in their hydrologic characteristics (infiltration, permeability, water holding capacity). These features are important because they effect the capacity of the soils to supply moisture to plants. In order that you may fully comprehend this basic effect, I would like to briefly review several important points:

1. The effect of increasing the concentration of soluble salts in soil is to increase the osmotic pressure of the soil solution. The effect of increased osmotic pressure appears to be a reduction in the range of available moisture that may be extracted by plant roots.
2. The increased osmotic pressure of the soil solution resulting from excess soluble salts is additive to the inherent soil-moisture-tension

(i.e. molecular attraction of the surface of soil particles for water) in limiting the availability of water to plant roots. The sum of the soil-moisture tension and osmotic pressure of the soil solution is termed the "total soil-moisture stress." The total soil-moisture stress is one of the most important factors governing the growth of plants regardless of whether this stress arised primarily from soil-moisture tension or the osmotic pressure of the soil solution. Interpreted in another way we might say that this principle tells us that a plant tolerant of excess soluble salts in soils may also be tolerant of drought.

3. In considering the presence of excessive quantities of soluble salts in soils, attention needs to be given to the nature of the constituent ions. Specific ion effects (toxicities and nutritional disturbances) need to be superimposed upon the osmotic pressure - affecting plant growth further. Most research on the effect of specific ions has been done on cultivated crops. The effects on range plants has not been comprehensively investigated. Except for the specific effects of sodium, my discussion will primarily stress the effects of salinity, because the effects of specific ions tends to be over-shadowed at the salt concentrations encountered in the soils discussion.

4. Excessive concentrations of sodium ion in soils tends to primarily exert important secondary effects on plant growth by adverse modification of physical and chemical characteristics. In the presence of excess sodium ion soils tend to disperse and puddle, thereby resulting

in poor aeration, and slow infiltration and permeability. Excess sodium also appears to cause some serious nutritional disturbances. The availability of calcium, magnesium, iron and other elements is markedly effected in soils having a high exchangeable sodium percentage.

The soils that blanket the Salt Desert Shrub area have resulted from the integrated action of 5 factors: (1) climate; (2) vegetation or biological; (3) parent material; (4) relief; and (5) time. In every situation each of these factors has some effect, but the effect of one or two may often over-shadow the effects of the others. Each different combination of the factor results in a different soils. Thus it is possible to have a great many different kinds of soil - each with a characteristic climate, biological population, mineralogy, physiography, and chemical and physical properties. An understanding of the action of the soil-forming factors in the Salt Desert Shrub zone may perhaps develop a better appreciation in regard to the major kinds of soil that occur in the area.

Climate

The major effect of climate in the zone appears to be that of aridity. Low amounts of moisture either due to low annual precipitation or to the ability of the soil to infilter precipitation is insufficient to provide for complete leaching. As a consequence, salts derived from weathering or dust tends to accumulate within the soil profile. The major portion of the soils within the area are dry during most of the year. This is especially true during the spring, summer, and fall

months when soil temperatures are at an optimum to speed-up chemical reactions. As a consequence, weathering of parent materials proceeds at an extremely slow rate, and may be limited to very short periods of the year and within the upper 12 to 18 inches of soil.

Vegetation

The vegetation peculiar to the area developed with the soil. Like the soils it reflects the integrated effects of the environment. The major kinds of plants are those capable of extracting soil moisture at high total soil-moisture stress. Because of sparse vegetative growth only small amounts of organic matter are returned to the soil. The soils consequently contain low amounts of organic matter and surface horizons tend to be thin and light colored. Some plants tend to recirculate salts from deeper horizons. Such plants accumulate salts in leaves and other parts and return the salts to the surface soil by exudation and leaf litter.

Parent materials

Studies of soils in the area indicates that the texture and mineralogy of the parent materials have a strong influence upon the kinds of soils formed in the area. Since there is a wide range in the kinds of parent materials available for soil formation, this is an important factor.

The nature of the parent material has a decided effect upon the kinds and amounts of soluble salts released by weathering; the rate of weathering; and the kinds of soil horizons that may develop.

Soils formed in parent materials derived from limestone, dolomite, or other highly carbonatic material for example, tend to develop horizons

of lime accumulation. Clays and horizons of clay accumulation do not form because minerals that weather to clay may not be present. The major weathering process under the deficient moisture condition appears to be the solution and redeposition of lime.

Soils formed in parent materials containing appreciable amounts of minerals that weather to clays tend to develop horizons of clay accumulation. Such horizons are often underlain by horizons having accumulations of lime derived from weathering and dust.

Sands composed primarily of quartz grains do not tend to form soil horizons because weatherable minerals are not present. Salts and lime are frequently present in such soils, but have been derived primarily from dust.

Relief

The primary influence of relief appears to be its effects on drainage and stability of landscapes.

Flat depressional areas tend to favor the accumulation of moisture and salts. Soils in such areas may contain higher contents of organic matter because of more luxuriant plant growth, and under some circumstances horizons of salt accumulation.

Steep, convex relief in contrast to flat depressional areas, tend to accelerate runoff. Thus the amount of precipitation entering the soil and available for the growth of plants and weathering is further limited. If the parent materials are erosive, the material may be stripped faster than the rate of soil formation and consequently soils with discernible horizons may not be present.

Time

Under present climatic conditions soil formation is probably taking place at a very slow rate. On recent or young landscapes soil horizons are often not present or only weakly developed. In contrast to this the soils on the older landscapes nearly always have well developed, easily discernible horizons.

Although the climate of the area is presently arid, studies concerned with stratigraphy and the evolution of landscapes indicate that it has not always been so. In the past 25,000 to 30,000 years the climate fluctuated through several pluvial (wet) periods and several interpluvial periods having a climate much like that experienced at the present time. During these climatic fluctuations optimum conditions for rapid soil formation occurred. Land surfaces that remained stable through these periods reflect the effect of soil formation in their present day occurrence. In contrast to the soils on these older landscapes, those formed on landscapes that evolved during the last pluvial period (about 5,000 to 7,000 years previous to present time) reflect only slight soil development.

Because there are a great number of different kinds of soil in the area, a cursory acquaintance with their characteristics might best be obtained by reviewing their classification in the higher categories of the National System of Soil Classification. This classification system has only recently been adopted and provides for six levels of classification: Order, Suborder, Great Group, Subgroup, Family, and Series. (See Table 7 - Classification of Salt Desert Shrub Area Soils.) I will review their classification here in the Order, Suborder, and Great Group categories.

Our present knowledge from soil survey indicates that most of the soils may be placed in 3 Orders, 6 Suborders, and 12 Great Groups. This

is a relatively small segment of the continuum of soil blanketing the continents of the earth when one realizes that the classification system provides for the placement of the known soils of the world in 10 Orders, about 25 Suborders, and some 200 Great Groups.

ORDER ENTISOLS

The Entisols are the young soils either lacking natural genetic horizons or with only the bare beginning of such horizons. They occupy low bottomland or alluvial fan positions, but also occur in uplands on bedrock or unconsolidated materials. Because of the past geologic history of the region under consideration, the Entisols are probably most extensive in the desert mountains of the Salt Desert Shrub area. We are primarily concerned with 3 Suborders and 4 Great Groups of the Entisols.

Suborder Psamments - This Suborder includes the sands and loamy sands that have a depth of either 40 inches or more; or are underlain by a rock contact if shallower. Since the Psamments in desert areas are often wind modified they may be encountered on most any kind of landform.

Great Group Torripsamments - These are the Psamments that are of major importance in the Salt Desert Shrub area. Included are the sandy soils that are usually dry (6 months of the year) in all parts between 10 inches and 40 inches or to a rock contact if present. Because the Torripsamments are able to infilter most of the rainfall that falls on them, they are highly productive for the area. When abused, however, they erode severely and are difficult to stabilize. Most of the Torripsamments are free of excess salts, but have low water holding capacity. Typical shrubs occurring on them include greasewood, fourwing saltbush,

hopsage, dalea, and species of horsebrush. Typical grasses include Indian ricegrass, sand dropseed and some needlegrasses. Torripsamments containing a considerable amount of gravel and stone are usually found to support shadscale and bud sagebrush as dominant species.

Selected laboratory and related data for a Torripsamment located near Fallon, Nevada is presented in Table 1.

Suborder Fluvents - This Suborder of the Entisols includes the soils having textures finer than loamy sand. They generally occupy low bottoms, alluvial fans, or similar positions that are receiving deposition. Most of them are subject to periodic flooding by runoff. Organic matter in these soils decreases irregularly with depth or remains above 0.2% organic carbon to 50 inches, thus reflecting a rather continuous process of sedimentation.

Great Group Torrifluvents - Includes the Fluvents that are usually dry. They may or may not be saline, depending upon drainage and salinity of parent materials. Conductivities, however, generally increase with depth. Because of additive water from runoff, they have good productive potential and may be adapted to improvement practices such as water spreading. Typical vegetation on saline Torrifluvents includes greasewood, quailbush, and some shadscale and saltgrass. On nonsaline areas, winterfat, fourwing saltbush, greasewood and rabbitbrush, and sagebrush may be present.

Selected laboratory and related data for a Torrifluvent located in eastern Lincoln County, Nevada is presented in Table 2.

Suborder Orthents - These are the Entisols with textures finer than loamy sand and organic matter content that decreases regularly with depth or that stays below a value of 0.2% organic carbon to 50 inches.

Great Group Torriorthents - Includes the Orthents that are usually dry. They may occur on slopes greater than 25%, and are generally less favorable from a production standpoint than are the Torrifluvents. They may or may not be saline depending upon drainage and the salinity of parent materials. The Torriorthents are extensive in desert mountains where they usually are underlain by bedrock. Typical vegetation on Torriorthents includes shadscale, bud sagebrush, wolfberry, hopsage and some winterfat and fourwing saltbush. Indian ricegrass, galleta grass and some needlegrasses are the most common grasses encountered.

ORDER ENCEPTISOLS

This Order includes soils with one or more genetic horizons that are thought to develop quickly and do not represent significant soil formation nor extreme weathering. They are found on young, but not recent landscapes. One Suborder is of importance in the Salt Desert Shrub region.

Suborder Aquepts - These are the Enceptisols that are saturated with water at some season. The ones that concern us the most here are those that have had a redistribution of salts and/or exchangeable sodium by high water table.

Great Group Halaquepts - This Great Group includes those Aquepts that have sodium saturation that is $\geq$ 15% in some part of the upper 20

inches and that decreases with depth below 20 inches. Such soils are common on lacustrine plains and stream flood plains in the Salt Desert zones. Textures include silt loam, clays and intermediate textures. Many of the soils are highly saline and plant cover may be limited to plants such as shadscale, pickleweed, seepweed, saltgrass and alkali sacaton. Greasewood is common on both saline and nonsaline soils of the Great Group.

ORDER ARIDISOLS

The Aridisols include the soils of dry regions that have been subjected to more intensive weathering than have the Entisols and Enceptisols. They have light colored surfaces and include the major area of soil with which you are concerned at this conference.

Aridisols are subdivided into two Suborders (the Orthids and Argids) and nine Great Groups, eight of which are frequently encountered in the Salt Desert Shrub zone.

Suborder Orthids - This includes those Aridisols without textural B or natric horizons. They must have: (1) a cambic horizon (color or structural B); or (2) a calcic ($>$ 15% $CaCo_3$ accumulation); or (3) a gypsic horizon ($>$ 5% $CaSO_4.2H_2O$) accumulation; or (4) a duripan (silica-cemented horizon; or (5) a salic horizon ($>$2% salt accumulation). The Orthids are extensive and important in the use and management of Desert soils.

Great Group Calciorthids - These are the Orthids with a calcic or gypsic horizon within 40 inches of the surface. The lime may have come from weathering of parent material or from dust. The lime in calcic

horizons may vary from soft and powdery material in the younger soils to a massive concrete-like indurated horizon in the older soils in the Group.

Calciorthids with gypsic horizons are not as widespread as those with calcic horizons and are more frequently encountered in the southern portion of the zone.

Calciorthids have apparently developed over a rather long period of time and most of them have a vesicular crust and gravel pavement that is most strongly expressed in the oldest soils. We also find that many Calciorthids are not always saline. Those that contain soft powdery calcic horizons are more apt to be saline than those with indurated horizons.

In the zone under consideration Calciorthids are capable of supporting a rather wide variety of vegetation depending upon the presence and depth to an indurated calcic horizon, the degree of development of a vesicular crust and gravel pavement, and the presence of salt in the root zone. Black sagebrush commonly associated with winterfat, shadscale, little rabbitbrush, and Indian ricegrass and squirreltail occur on the northern Calciorthids that contain low concentrations of salts in the root zone. On the southern counterpart to these, blackbrush, Nevada ephedra, shadscale, and some galleta grass are common. On the more saline Calciorthids and Calciorthids having low water holding capacity shadscale and bud sagebrush occur most frequently in mixed stands. Because of high lime content Calciorthids are frequently deficient in available phosphorous, iron, and other nutrients.

Selected laboratory and related data for a Calciorthid located near Alamo, Nevada is presented in Table 3.

Great Group Camborthids - These are the Aridisols that have only a cambic horizon. These are the youngest of the Aridisols and have been found for the most part on landscape surfaces developed in the late Pleistocene. The cambic horizon is usually weakly prismatic and if lime is present some leaching of the lime has taken place. The Camborthids are widespread in the Salt Desert Soil zone and usually have salts accumulated in the profile at different depths depending upon texture, precipitation, and hydrologic' characteristics of the profile.

The Camborthids having favorable infiltration, water holding capacity, and those occurring in more humid portions of the zone have fair productivity. Common plants associated with Camborthids include winterfat, fourwing saltbush, Nevada ephedra, shadscale, horsebrush, little rabbitbrush, bud sagebrush, wolfberry, and spiny hopsage. Indian ricegrass, squirreltail, and needlegrasses are commonly associated grasses.

Great Group Durorthids - The Durorthids include the Aridisols having a duripan (silica-cemented pan) within 40 inches of the surface. They characteristically have a vesicular crust and an increasing salt content with depth. Textures may include loamy sands and clays, but the medium and moderately fine textures seem to predominate. The Durorthids with the duripan at shallow depths appear to support broad associations of shadscale and bud sagebrush. On nearly level topography

upland greasewood, and graymolly also become important constituents. As the depth to duripan increases, wolfberry, hopsage, galleta grass and some Indian ricegrass tend to predominate. This is particularly true in the more southerly part of the zone on soils with moderately coarse texture.

Selected laboratory and related data for a Durorthid located approximately 20 miles south of Winnemucca, Nevada is presented in Table 4.

Great Group Salorthids - These are the Orthids that have a salic horizon (salt horizon with > 2% salt) and a water table at some season at less than 40 inches. Capillary rise and evaporation concentrate the salts, usually near the surface. The Salorthids are of limited extent in the Salt Desert Shrub zone and are normally located on flats and in depressions where soil textures are fine and drainage is restricted. Plant cover normally consists of greasewood, seepweed, and saltgrass. In areas that are very highly saline, samphire and pickleweed tend to predominate.

Suborder Argids - The Argids are the Aridisols having horizons of clay accumulation. The Argids are extensive soils in the Salt Desert Shrub zone supporting a rather wide variety of plants.

Great Group Nadurargids - As the name implies, these are the Argids having a natric horizon (textural B horizon with > 15% ESP) above a duripan. They have light colored vesicular crusty surface horizons and usually an increase in soluble salts with increasing depth. The texture of the natric horizon ranges, in most cases, from a clay loam

to clay. The Nadurargids support broad associations of shadscale, bud sagebrush, wolfberry and upland greasewood. In some places considerable hopsage in association with wolfberry may be encountered. Galleta grass and Indian ricegrass are the grasses most frequently encountered. Wet Nadurargids usually support greasewood, shadscale, and some salt grass.

Great Group Durargids - The Durargids are the Argids having an argillic horizon (textural B horizon with < 15% ESP) and a duripan. Like the Nadurargids they have vesicular crusts, and the textures of the B horizon range from clay loams to clay. The B horizon of the Durargids lacking excessive exchangeable sodium does not tend to disperse, and consequently has more favorable structure and permeability. Most Durargids in the Salt Desert Shrub zone tend to have increasing salinity with depth. The vegetation supported by the Durargids in the Salt Desert Shrub zone is very similar to that supported by Nadurargids.

Selected laboratory and related data for a Durargid located in western Lincoln County, Nevada is presented in Table 5.

Great Group Natrargids - The Natrargids include the Argids with a natric horizon. The natric horizon of most Natrargids ranges in texture from clay loams to clay and because of high exchangeable sodium disperse readily, and have rather slow permeability. The concentration of soluble salts increases with depth, and may be rather high in the lower part of the natric horizon and underlying horizons. Natrargids may occur both in well-drained positions, and on flats and flood plains

where they are subject to some water-logging in the lower portion of the profile. Natrargids are extensive soils in the Salt Desert Shrub area, and in well drained positions support shadscale, bud sagebrush, horsebrush, spiny hopsage, upland greasewood, graymolly and some squirreltail and galleta grass. Wet Natrargids support mostly big greasewood, rubber rabbitbrush, and some saltgrass.

Great Group Haplargids - The Haplargids include the Argids with an argillic horizon that may or may not be underlain by a calcic horizon. The B horizon characteristically ranges from a clay loam to a clay and contains $<15\%$ exchangeable sodium. The concentration of soluble salts characteristically increases with depth but may not be excessively high. The Haplargids are extensive and support in northern areas mixtures of shadscale, bud sagebrush, winterfat, little rabbitbrush, squirreltail and Indian ricegrass. In southern areas they support, in addition to shadscale and bud sagebrush, species of horsebrush, wolfberry, spiny hopsage, and considerable galleta grass.

Selected laboratory and related data for a Haplargid in western Lincoln County, Nevada is presented in Table 6.

The climate of the Salt Desert Shrub area together with the major kinds of soils that have developed in the area presents a special kind of environment that is not especially favorable for the production of large amounts of vegetation. A number of problems are limiting factors in this environment among which the following particularly stand out.

1. The major area of soils have adverse hydrologic characteristics:

A. Infiltration rates are low. Many of the soils have strongly

developed vesicular crusts and also in many cases a dense gravel pavement. The surface horizon of many soils also disperses badly.

B. Permeability of large areas of soils is slow due to the presence of natric horizons, duripan or indurated calcic horizons.

C. Large areas of soils have low moisture supplying capacity due either to one or more of the following:

(1) Limited depth for storing moisture.

(2) Low water holding capacity due to coarse or gravelly textures.

(3) Additive soil-moisture stress resulting from increased osmotic pressure of the soil solution.

2. The soils have an inherently severe erosion potential.

A. Wind is ever active and can be an efficient erosion agent.

B. Adverse hydrologic characteristics (low infiltration, slow permeabilities) are conducive to severe erosion under the kinds of storms characteristic to the area.

3. The climate is arid and severely limits alternatives for management and improvements.

A. The average annual precipitation ranges from about 4 to 8 inches and is quite variable from year to year

B. The annual pattern of precipitation is quite variable from place to place.

C. High velocity winds and high intensity convection storms are common.

D. The low annual precipitation does not generally provide for leaching, consequently salts derived from weathering of parent material and dust tend to accumulate at various depths in the soil profile.

The interactions among the foregoing features and others can indeed produce a severe environment. As a consequence it is generally accepted that total potential yield is low. Some of the soils, particularly the Psamments, and the Fluvents, and others receiving additional moisture from runoff are known to produce higher yields. These, however, represent a relatively small portion of the total area.

Some areas of soils that receive additional moisture from runoff (particularly the Fluvents) have good possibility for improvement of specie composition and yield with known practices such as water spreading and seedings. For the larger proportion of the area, however, our technical knowledge has not reached a level whereby we can accomplish rapid desirable improvements in the vegetative cover, as is done in more humid areas. Field scale plantings of shrubs and grasses cannot be accomplished with any confidence of success. Risks of erosion under prolonged denuded plant cover is always a problem. Any practice that involves an erosion risk needs to be avoided until such a time when we may learn how it can be properly applied.

Because of the erosive nature of the soils and fragile vegetative cover, the major objective of land managers should be to conserve the soil resource. Alternatives available to him to accomplish this job are practically limited to application of principles of range

management for maintaining a desirable vegetative cover, and certain engineering practices such as contour furrowing on critical areas, channel stabilization, and water retarding structures. Disturbance of the soil in connection with any use should be avoided as much as possible without an understanding of the consequences.

Although we may anticipate that productivity under the climate of the area cannot be especially high, I am confident that research in time will give us the technical knowledge to manipulate both soils and vegetation to achieve certain objectives consistent with the various uses to which the Salt Desert Shrub area is subjected. Research applicable to the area has in the past been limited, but some of the current work is encouraging. The future needs, however, because of increasing uses for purposes in addition to grazing, are immense. It will need to include work in the fields of soils, engineering, climate, plant genetics, plant physiology, and plant pathology as well as the numerous interactions that are involved.

We cannot expect the land manager to supply anticipated future demands upon the area unless he has the technical knowledge available to undertake considerable improvements involving manipulation of soils, vegetation, and hydrology. If the technical knowledge is not provided, it may become necessary in the future to impose some rather serious restrictions on the use of the land.

TABLE 1

Selected laboratory and related data for a Torripsamment located near Fallon Nevada. 1./

Average Annual Temperature: 50.6° F.
Frost-free Season 32° F.: 130 days
Average Annual Precipitation: 5.34 inches
Elevation: 4,000 feet
Vegetation: Dalea, spiny hopsage, Indian ricegrass, and annuals.

Depth (inches)	Particle Size Distribution Sand (%)	Silt (%)	Clay (%)	Textural Class	Organic Carbon (%)	ECx10^3 @ 25°C	15 ATM (%)	CEC m.e./100 gm	ESP	Sat. (%)
0 - 4	93.5	3.4	3.1	sand	0.10	0.4	2.0	5.1	4	24.6
4 -25	93.6	1.0	5.4	sand	0.06	0.3	2.3	5.6	4	24.2
25-41	94.9	4.1	1.0	sand	0.03	0.3	2.0	5.6	5	25.1
41-60	98.4	0.8	0.8	cos	0.00	0.3	1.3	4.6	7	24.8

1./ SCS - Soil Survey Laboratory data.

TABLE 2

Selected laboratory and related data for a Torrifluvent located in Eastern Lincoln County, Nevada. 1./

Average Annual Temperature: About 52° F.
Frost-free Season 32° F.: About 140 days.
Average Annual Precipitation: About 6 inches.
Vegetation: Winterfat and fourwing saltbush with traces of Indian ricegrass and galleta grass.

Depth (inches)	Particle Size Distribution Sand (%)	Silt (%)	Clay (%)	Textural Class	Organic Carbon	ECx10^3 @ 25°C	15 Atm (%)	CEC m.e./100 gm	ESP	Sat. (%)
0 - 3	79.0	18.4	10.5	fsl	0.28	4.6	7.4	24.1	1	24.3
3 - 13	66.1	19.6	13.2	fsl	0.22	0.4	8.9	25.4	1	27.3
13 - 20	60.5	25.2	14.3	fsl	0.21	0.4	10.2	30.0	3	32.7
20 - 39	52.9	35.5	11.6	fsl, l	0.21	0.9	9.8	28.8	7	33.7
39 - 45	83.1	8.5	8.4	glcos	0.06	12.4	5.4	16.2	8	23.2
45 - 57	31.4	48.4	20.2	l	0.14	18.6	12.9	34.4	20	38.3
57 - 64	74.2	17.1	8.7	cosl	0.04	14.0	5.0	12.3	11	22.7

1./ SCS - Soil Survey Laboratory data.

TABLE 3

Selected laboratory and related data for a Calciorthid located near Alamo, Nevada. 1./

Average Annual Temperature: 56.6° F.
Frost-free Season 32° F.: 166 days
Average Annual Precipitation: 6.97 inches
Elevation: 3,820 feet
Vegetation: Shadscale, and some spiny hopsage, creosotebush, cacti and yucca.

Depth (inches)	Particle Size Distribution Sand (%)	Silt (%)	Clay (%)	Textural Class	$CaCo_3$ Equiv. (%)	$ECx10^3$ @ 25°C	15 Atm (%)	CEC m.e/100 gm	ESP	Sat. (%)
0 - 1 2/	88.7	8.5	2.8	cos	3	0.4	3.3	5.2	4	19.8
1 - 4 3/	78.5	6.2	15.3	cos-cosl	7	0.3	5.2	5.6	7	17.8
4 - 11	85.1	3.9	11.0	cosl	8	0.3	9.2	14.1	2	23.0
11 - 19 4/	82.7	4.9	12.4	gcosl	24	0.4	12.8	15.6	6	31.1
19 - 33 4/	84.8	5.6	9.6	lcos	14	0.9	9.0	13.1	18	32.8
33 - 43	90.3	3.0	6.7	cos	6	2.3	5.2	9.3	26	30.2
43 - 50	92.0	2.4	5.6	cos	1	3.5	4.5	7.3	23	30.8

1./ SCS - Soil Survey Laboratory data.
2./ Loose sand layer.
3./ Vesicular crust.
4./ Indurated calcic horizon.

TABLE 4

Selected laboratory and related data for a Durorthid located approximately 20 miles south of Winnemucca, Nevada 1./

Average Annual Temperature: About 49° F.
Frost-free season 32° F.: About 125 days.
Average Annual Precipitation: About 7-8 inches.
Elevation: 4,800 feet.
Vegetation: Nearly a pure stand of shadscale and bud sagebrush with some aquirreltail and Sandberg bluegrass.

Depth (inches)	Particle Size Distribution Sand (%)	Silt (%)	Clay (%)	Textural Class	$CaCo_3$ Equiv. (%)	$ECx10^3$ @ 25°C	15 Atm. (%)	CEC m.e/100 gm	ESP	Sat. (%)
0 - 2 2/	32.5	58.6	8.9	sil	-	1.1	7.1	18.3	3	36.3
2 - 4 2/	32.4	58.1	9.5	sil	-	0.8	7.9	20.4	6	33.8
4 - 10	32.3	58.5	9.2	sil	-	0.4	8.0	19.0	4	32.4
10 - 14	28.7	61.2	10.1	sil	-	0.7	7.6	18.6	20	24.3
14 - 17	30.7	61.0	8.3	sil	-	0.9	7.7	19.2	31	26.5
17 - 21	36.5	56.3	7.2	sil	<0.5	1.9	7.8	22.4	38	28.8
21 - 28 3/	39.7	48.3	12.0	gl	4	7.1	8.3	22.4	47	31.5
28 - 35 3/	49.2	28.1	22.7	gl	5	17.2	9.4	22.2	48	32.0
35 - 42	57.9	23.2	18.9	gcosl	<0.5	27.5	8.7	19.7	53	30.2
42 - 48	66.2	24.1	9.7	gcosl	4	29.4	9.8	27.5	35	37.4
48 - 56	59.2	27.3	13.5	gcosl	3	29.7	10.3	25.4	39	36.3

1./ SCS - Soil Survey Laboratory data.
2./ Vesicular crust.
3./ Duripan

TABLE 5

Selected laboratory and related data for a Durargid located in western Lincoln County, Nevada. 1./

Average Annual Temperature: About 52° F.
Frost-free Season: About 150 days.
Average Annual Precipitation: About 7-8 inches.
Elevation: 4,780 feet
Vegetation: Shadscale and graymolly with traces of fourwing saltbush.

Depth (inches	Particle Size Distribution Sand (%)	Silt (%)	Clay (%)	Textural Class	$CaCo_3$ Equiv. (%)	ECx10^3 @ 25°C.	15 Atm (%)	CEC m.e/100 gm	ESP	Sat. (%)
0 - 3 2/	73	16.8	10.2	cosl	2	1.0	6.3	19.4	5	16.5
3 - 7 3/	57.5	17.7	24.8	scl	Tr.	0.6	14.9	27.8	5	25.7
7 - 11 4/	75.1	13.5	11.4	sl	1	0.6	7.6	20.3	8	28.3
11 - 24	75.5	16.0	8.5	sl	Tr.	0.5	6.3	17.4	13	23.3
24 - 32	65.9	24.2	8.9	fsl	Tr.	2.8	7.0	20.6	27	24.3
32 - 40	39.1	44.7	16.2	l	1	12.9	14.8	33.3	28	44.0
40 - 60	20.4	54.1	24.5	sil	1	18.7	22.3	40.1	27	51.0

1./ SCS - Soil Survey Laboratory data.
2./ Vesicular crust
3./ Argillic horizon
4./ Duripan

TABLE 6

Selected laboratory and related data for a Haplargid located in western Lincoln County, Nevada 1./

Average Annual Temperature: About 52° F.
Frost-free Season 32° F.: About 150 days
Average Annual Precipitation: About 7-8 inches.
Elevation: 5,000 feet.
Vegetation: Hopsage, horsebrush, bud sagebrush, shadscale, wolfberry and galleta grass.

Depth (inches)	Particle Size Distribution Sand (%)	Silt (%)	Clay (%)	Textural Class	$CaCo_3$ Equiv. (%)	ECx10^3 @ 25°C.	15 Atm (%)	CEC m.e/100 gm	ESP	Sat. (%)
0 - 3 2/	73.3	21.9	4.8	cosl-glcos	Tr.	0.6	4.3	13.4	6	14.9
3 - 5	57.2	17.2	25.6	scl	Tr.	0.5	9.8	22.8	7	23.5
5 - 11 3/	47.7	9.3	43.0	sc	Tr.	0.8	19.3	34.3	9	45.2
11 - 17 3/	47.4	11.4	41.2	sc	4	1.4	19.5	33.0	10	46.9
17 - 22 4/	69.6	14.7	15.7	gcosl	16	2.6	11.8	25.5	10	41.3
22 - 44	88.9	5.4	5.7	gcos	6	5.3	5.5	11.6	17	27.2
44 - 50	89.7	5.3	5.0	vgcos	14	5.4	5.9	11.3	19	38.9
50 - 60	96.9	1.1	2.0	gcos	1	4.0	3.0	7.7	17	28.3
60 - 64	90.8	3.6	5.6	vgcos	14	5.3	7.1	10.0	16	41.0

1./ SCS - Soil Survey Laboratory data.

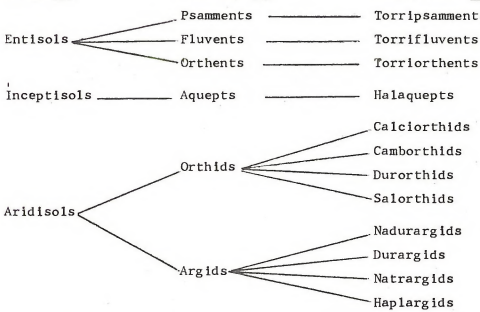
2./ Vesicular crust

3./ Argillic horizons.

4./ Calcic horizon.

TABLE 7

Classification of the Major Soils of the Salt Desert Shrub Area in Orders, Suborders, and Great Groups of the National Soil Classification System 1./



1./ Names of Suborders and Great Groups are tentative and subject to revision.

2./ Groupings made primarily on generalization of common properties.

3./ Differentiated on: (1) chemical and physical properties that reflect either water-logging or genetic differences due to climate and vegetation or; (2) chemical or mineralogical properties that include extremes of textures, and presence of large amounts of amorphous clays or free sesquioxides in the clay fraction.

4./ Subdivisions of Suborders based largely on the presence or absence of diagnostic horizons (argillic, calcic, etc.) and the arrangement of these horizons.

5./ Subdivisions of the Great Group including a central concept of the Great Group and fringe Subgroups where properties of one Great Group tend to merge with others.

6./ Subdivisions of Subgroups that are differentiated primarily on the basis of properties important to the growth of plants - texture, mineralogy, water holding capacity, soil temperature, reaction, etc.

7./ A collection of soil individuals essentially uniform in differentiating characteristics and arrangement of horizons.

Erosion-characteristics of Salt Desert Shrub Areas

Norman J. King

INTRODUCTION

Many of you attending this symposium probably associate the term "salt desert shrub" with a desert landscape characterized by a sparse plant cover, fine-grained saline soils, excessive runoff, and active sheet, rill, gully, and/or eolian erosion. This impression certainly fits the vast outcrop areas of low-permeability shale of Cretaceous age that comprise the bulk of the "frail lands" administered by the Bureau of Land Management. You will recall from earlier papers presented at this symposium, however, that salt desert shrubs also grow in areas where high total soil-moisture stress may be a consequence of simple aridity, that is, inadequate precipitation to support other plant types. Such areas are common in the Basin and Range Province and are typically represented at the Desert Experimental Range, which we shall visit. Soils in these areas are generally rocky, comparatively low in salinity, and moderately permeable. Surficial runoff is virtually nonexistent, and eolian erosion is minimized by a covering of desert pavement. All gradations from the highly eroding areas underlain by Cretaceous shale to the noneroding areas in the more arid parts of the Basin and Range Province can be found in the field. It follows, therefore, that erosion characteristics of salt desert shrub areas differ widely from one locality or region to another. Thus, the presence of salt desert shrubs in an area may not be indicative in any way of the specific erosion problems that might exist or that might occur in the future within that area.

Although salt-desert shrubs may not be an erosion criterion in themselves, the fact remains that some salt desert shrub areas are among the most severely eroding localities in the Rocky Mountain region. Those of you charged with the responsibility of managing these dissected ranges must recognize and understand the problem at hand before you can hope to cope with it. This requires some understanding of basic principles of erosion and sedimentation. For example, you must understand the difference between geologic erosion and so-called accelerated erosion. What causes accelerated erosion and what are the best methods of treatment? What role does management play? Although time does not permit a detailed discussion of these subjects, I would like to touch briefly on those aspects of the erosion problem that I believe pertain directly to conservation practices on the public domain.

THE EROSION PROBLEM

First, what is the erosion problem? Stated succinctly, it is the change in environment from one of general stability with some "natural geologic erosion" on the steeper slopes balanced by net aggradation along the drainage courses, to one of valley trenching, head cutting, and related forms of "accelerated" erosion. Economic consequences include generally: greatly increased sediment yield to downstream areas; deterioration of much of the most productive forage lands as valley floors are dissected; lowering of water tables to the level of the newly incised gully bottoms; and concentration of floodwaters, that once afforded natural irrigation, to raging torrents in narrow arroyos.

NATURAL GEOLOGICAL EROSION VS. ACCELERATED EROSION

Clarification of the terms "natural geologic erosion" and "accelerated erosion" requires a brief review of geomorphic processes in arid and semiarid regions. The desert landscape in areas not complicated by structural deformation is characterized by three basic land forms. They are the hillslope, the intermediate area, and the lowland. The hillslope is the area of moderate to great relief usually around the periphery of a basin that is subject to continuous erosion, generally sheeting, rilling, and mass wasting. The intermediate area is the comparatively gently sloping area that abuts the base of the hillslope at a conspicuous angle and slopes downward, merging almost imperceptibly into the lowland. The intermediate area is essentially a stable surface of transport left behind as the hillslope gradually wears away and retreats towards the drainage divide. The slope of the intermediate area continuously adjusts to changes in environmental factors so as to remain in quasi-equilibrium with the water and sediment shed from the adjacent hillslopes. If the slope of the intermediate area is too steep, it is lowered by erosion; if the slope becomes deficient for any reason, then sediment from the hillslopes accumulates to increase the slope of the intermediate area until quasi-equilibrium is again established.

The lowland functions as nature's temporary sediment depository where all or a part of the sediments derived from erosion on the hillslope may be periodically stored. Aggradation, once started, may continue for protracted periods numbered in decades or even centuries. During this time the rate of sediment yield from a basin may be greatly reduced below the long-term average. Sediments accumulating on the lowlands during a period of aggradation are generally stabilized and protected by a plant cover supported by natural irrigation as water and sediment are spread over the broad untrenched valley bottoms. The sediments in themselves, however, possess little inherent resistance to erosion and are always subject to rapid removal by gullying processes if the protective plant cover is depleted or appreciably disturbed.

The reduced rates of sediment yield from a basin during periods of aggradation are balanced by correspondingly high rates of sediment yield during periods of erosion. Conservationists often refer to periods of low sediment yield as representing normal geologic erosion and to periods of high sediment yield as representing accelerated erosion. This concept is misleading. Periods of high sediment yield when lowlands and intermediate areas are being rapidly dissected and sediment from the hillslope is supplied directly to the drainage net certainly do represent accelerated erosion. Periods of low-sediment yield when much of the sediment eroded from the hillslope is deposited on the lowland within a basin, however, do not afford a measure of normal geologic erosion.

I prefer to think of normal geologic erosion in the arid and semiarid environment as being approximately equivalent to hillslope erosion, which I regard as the primary source of virtually all sediments ultimately moved out of a basin. Epicycles of erosion and aggradation on the lowland interrupt the movement of sediment off the hillslopes and out of a basin without significantly affecting the long-term rate of sediment yield. Hence, at any instant of geologic time the rate of sediment yield from a basin may be considerably higher or lower than the long-term average representing normal geologic erosion, depending on whether the basin is undergoing a period of accelerated erosion or a period of aggradation. This is not to imply that rates of erosion on hillslopes are essentially constant over long periods and that fluctuations in the rate of sediment yield from a basin depend wholly on erosion or aggradation of the lowlands. On the contrary, rates of hillslope erosion probably also vary with the amount and pattern of precipitation, the condition of the plant cover, and use. Available data suggest that present rates of hillslope erosion may be somewhat greater than rates existing prior to the advent of white man and his use of the available forage resource for grazing livestock. This prospect is not entirely undesirable as the increased sediment yield affords a ready source of sediment for filling the gullies that are so common on the lowlands. The question is how can sediment eroded from the hillslopes through processes of natural geologic erosion be effectively used to heal the dissected lowlands?

NATURAL PROCESSES OF EROSION AND AGGRADATION IN EPHEMERAL STREAM CHANNELS

While man has struggled with minimal success to control accelerated erosion in arid and semiarid regions, it is intriguing to note that many alluvial valleys have repeatedly trenched and healed in the past, essentially in the absence of man's influence. It follows, therefore, that natural processes are such that areas of active gullying will ultimately tend to heal in time. Unfortunately, this realization offers no direct solution to the erosion problem as the time required for natural healing is considered too great under existing economic pressures. The distinct possibility exists, however, that the time required for natural healing of dissected valleys may be greatly shortened by devising and utilizing treatments and structures that augment the natural tendency of a gullied channel (arroyo) to reestablish a stable or aggrading environment. This approach requires an understanding of geomorphic processes in gullied ephemeral streams.

Most gullies are characteristically narrow and deep immediately after their inception. Walls are essentially smooth and steep with little or no vegetation or debris within the channel to impede flow velocities. According to equations relating flow velocity to channel width, depth, slope, and roughness, such as the Manning equation (King, et al., 1948, p. 247), mean velocity for a given discharge is greatest under these conditions. High mean velocity, in turn, reflects a correspondingly high traction force and capability for sediment transport which causes the stream to erode its banks. The rate of bank erosion depends on the amount and frequency of discharge and the duration of runoff in relation to the character of materials being eroded. High discharges are most erosive in gullies incised in relatively noncohesive sandy sediments. Prolonged flows are most erosive in gullies incised in fine-grained sediments that are cohesive and extremely resistant to erosion when dry, but soften and become highly erodible after prolonged wetting.

Gilbert (1914) recognized that "A free stream does not tolerate a straight channel. If a straight channel of moderate width be given to a stream, the current swings rhythmically to right and left, and if the banks yield it develops meanders." In this way a gully incised in unconsolidated sediments will widen progressively as the banks are eroded and will tend to develop a sinuous pattern. As the channel widens, the mean depth of flow for a given discharge decreases. Meandering, in effect, increases the length of the path of flow and thereby decreases channel slope. Thus, the natural tendency of a gully to widen and to meander introduces changes in channel morphology that result in decreased flow velocities.

Ultimately the gullied channel reaches a width at which the flow velocity is reduced to the extent that the stream can no longer carry its entire sediment load, and the coarser fraction is dropped. At first, aggradation is slow, and accumulating sediments are subject to scour during periods of high discharge. In time, however, the deposit becomes increasingly stable as a protective plant cover develops.

As aggradation continues, the blanket of alluvium accumulating within the channel absorbs more and more water during periods of flow. The effects are twofold. Water stored in the bank and bed deposits provides a source of soil moisture to sustain the developing plant cover between periods of runoff. Also, channel losses in ephemeral streams may significantly reduce peak discharges, thereby decreasing the velocity of the stream and furthering aggradation.

Eventually, the plant cover may develop to the extent that it overshadows all other factors tending to promote aggradation. Vegetation affords a hardy, resilient, self-maintaining obstruction to flows that greatly increases channel roughness, stabilizes accumulating sediments, and enhances infiltration during periods of flow. So long as the plant cover effectively limits flow velocities within the channel, aggradation may continue until the old channel is completely filled and flows once again spread across the valley floor. Should the plant cover deteriorate for any reason before the old gully is completely filled, however, or should an unusual flood produce local scour in the form of a headcut, a new cycle of valley trenching may occur. Cut and fill terraces are formed essentially in this manner.

METHODS OF INDUCING CHANNEL AGGRADATION

Conservationists have long recognized that any treatment practice that significantly reduces flow velocity in a channel will tend to reduce erosion and induce aggradation. The method most commonly used in the past to reduce flow velocity was to physically obstruct the current by placing barriers or planting vegetation within the channel (Bennett, 1939). This approach proved very effective in gullied humid areas where vegetation was easily established and enterprising farmers provided necessary management, maintenance, and modification of control structures. Channel barriers have proved to be comparatively unsuccessful, however, as a means of filling gullies in remote arid and semiarid regions where vegetation is comparatively difficult to establish and only minimal management, maintenance, and modification can be achieved.

Studies in Logan and Conant Creek basins in central Wyoming reveal a novel and promising way of inducing aggradation in gullies in arid and semiarid regions. In 1953 the Bureau of Land Management completed a flood control project on Logan Draw, an ephemeral stream that heads on Beaver Rim and trends generally northward to its junction with Conant Creek. Above the junction of Logan Draw and Conant Creek the drainage basins of the two streams are very much alike. Logan Draw has a channel length of 21.3 miles, a drainage area of 60.4 square miles, and a sandy bed that carries perennial underflow. Conant Creek above the junction has a channel length of 18.4 miles, a drainage area of 58.9 square miles, and a sandy bed that also carries perennial underflow. Both basins head at about the same altitude on Beaver Rim, experience the same general storm events, have similar topography, and are underlain by the same general rock types. It is probable, therefore, that prior to treatment, both streams flowed simultaneously, that peak discharges of about the same magnitude occurred at the junction about the same time, and that sediment loads were about equal. This reasoning is supported by a marked increase in channel width downstream from the junction of the two streams, which indicates adjustment to higher flow conditions than those experienced by either channel upstream from the junction.

Since completion of the control project, Logan Draw has contributed no flow to the reach downstream from the junction, whereas Conant Creek has flowed on a number of occasions. Thus, discharge in the reach downstream from the junction presumably has been cut about in half. As flows from Conant Creek spread across the comparatively wide gully bottom in the reach downstream from the mouth of Logan Draw, the channel aggraded.

Repeat surveys along monumented sections show that the channel was filled to a depth of almost 4 feet during the period 1954-65. Aggradation, facilitated by a rank growth of vegetation on the channel bed, which also affords protection against local scour, is now progressing upstream from the junction.

Similar, though less spectacular, aggradation is occurring in the main channel of Logan Draw downstream from the mouths of most uncontrolled tributaries. Deposition occurs as flows from the tributaries debouch into the comparatively broad main channel in which the flow has been largely eliminated by upstream reservoirs.

Channel aggradation in Logan Draw and in Conant Creek occurred for much the same reason that it does when a gully widens through natural processes of bank erosion. Withholding runoff in reservoirs in Logan Draw significantly decreased discharge in the drainage net downstream. This decrease in discharge resulted in a corresponding decrease in mean depth of flow, which is also the immediate effect of channel widening. The decrease in mean depth of flow, in turn, reduced flow velocities to the extent that aggradation occurred. It follows, therefore, that a reduction in discharge in a channel, whatever the cause, has essentially the same effect on flow velocity as channel widening. Thus, conservation practices that withhold runoff and thereby reduce discharge should augment the natural tendency of an ephemeral stream to aggrade as it progressively widens its channel through bank erosion.

A decrease in stream velocity does not necessarily mean that a channel will begin to aggrade, however. For example, a gully is generally so narrow immediately after its inception that even very small flows tend to undercut the banks and erode the channel. It is virtually impossible to induce aggradation in such a gully by decreasing discharge since almost any runoff will be erosive. If all flows are withheld from such a gully, it will no longer erode, but neither can it aggrade after having been deprived of its external source of sediment.

Studies in Bitter Creek basin in southeastern Utah show the negative effect of withholding both water and sediment from a narrow, deeply incised gully net. In 1950 a dam was built by the BLM across the channel of Bitter Creek at a point where the stream traverses a narrow V-notch eroded across a steeply dipping sandstone hogback on the east flank of the Waterpocket Fold. The reservoir thus formed had an initial capacity of 135 acre feet and spilled through a durable bedrock-controlled spillway. Total area upstream from the structure was 3.13 square miles, but only 2.55 square miles drained directly into the main reservoir. Runoff from the remainder of the basin (0.58 square mile) was controlled by 36 small reservoirs having an aggregate capacity (1950) of 9.4 acre feet.

During the period 1950-54, the reservoir filled to a depth of more than 10 feet with sediment which formed an alluvial wedge that extended almost 4,000 feet upstream from the dam. The deposit at its upstream end reached an elevation of almost 30 feet above the reservoir spillway level. Aggradation on the gully bottom in the reach upstream from the reservoir in effect increased channel width from less than 20 feet to 50-100 feet because of the greater width of the gully with increasing distance above the channel floor.

In 1954, approximately 450-500 small reservoirs or pits were excavated by a dozer in that part of the basin that formerly had drained directly through the gully net to the main reservoir. Although the capacity of individual structures averaged only about 0.1 acre foot, in aggregate these small reservoirs diminished runoff and sediment yield into and through the gully net. During the period 1954-64 the rate of channel filling in the reach upstream from the main reservoir decreased significantly, although sediment continued to accumulate in the reach that had been effectively widened by previous aggradation. Extension of the sediment deposit upstream slowed to a mere fraction of the rate during 1950-54. Channel resurveys showed no significant change during the period 1950-64 in the gully at a point 5,500 feet upstream from the dam. The gully in this reach is about 100 feet wide at the top, 15 feet wide at the bottom, and 44 feet deep. Meanwhile, the myriad of small reservoirs excavated in 1954 should have little or no lasting effect, either good or bad, on the morphology of the Bitter Creek channel. Most of these pits have largely filled with sediment or have been breached and are no longer functional.

These data emphasize (1) the futility of attempting to induce aggradation in a narrow gully by withholding water and sediment, and (2) the fact that aggradation can be induced by reducing discharge in a gully, the bottom of which has been widened appreciably through bank erosion or through aggradation induced by obstructing the current with reservoirs, check dams, vegetation, etc. So far as practical, treatment practices aimed at inducing aggradation in gullies by controlling runoff and reducing discharge should withhold as much water and as little sediment as possible from the drainage net. This can be accomplished by applying mechanical treatments and building structures mainly in those subbasins or areas that contribute relatively clear water to the drainage net. Treatment practices applied to noneroding areas have the advantage that they remain effective for much longer periods than similar treatments in actively eroding areas. No treatments should be applied to the more severely eroding areas as they provide the immediate source of sediment for filling downstream gullies. It might even be practical to augment local erosion in some headwater areas (Heede, 1965) so as to furnish more sediment and thereby accelerate the process of downstream gully filling.

THE ROLE OF MANAGEMENT IN EROSION CONTROL PROGRAMS

I would be negligent when addressing a group such as this not to emphasize the great importance of management in programs of erosion control. Available data strongly indicate that our erosion problems on public lands today are largely a consequence of man's abuse of these lands in the past. If so, future problems can be minimized through the application of good management practices today. In this sense I use the term "management" in its broadest context, i.e., all those things that you might do to insure the most judicious use of the lands administered by the BLM as well as the formulation, supervision, maintenance, and modification of all treatment practices applied to the public lands. This fact stands out: Good management is probably the only erosion-control measure that can be applied to a watershed in its entirety.

CONCLUSIONS

In summary I would like to emphasize these salient aspects of erosion-control on arid and semiarid lands.

1. The lowlands are the principal source of sediment during periods of accelerated erosion, and they are the best place to store sediment eroded from the adjacent intermediate areas and hillslopes. The major emphasis of erosion-control programs, therefore, should be directed towards treatment of the lowlands and restoration of gullied valley floors.

2. Not all gullied valley floors are equally amenable to treatment. Conservationists should not succumb to the temptation of attempting to restore the worst problem areas first. Their efforts should begin in those valleys where the gully net has widened to the extent that some local aggradation is already beginning.

3. Narrow gullies with severely eroding banks should be allowed to widen naturally to the extent that they will ultimately be amenable to treatment. Efforts to prevent erosion in such gullies are not only expensive and frustrating, but they tend to delay the time when restoration can begin.

4. Treatment practices aimed at controlling runoff should be designed and distributed across a basin so as to achieve the most uniform decrease in discharge possible throughout the drainage net. Then aggradation would tend to occur the length of the gully rather than locally downstream from major junctions such as in the Logan Draw-Conant Creek study.

5. So far as practical, treatments aimed at reducing discharge should withhold as much water and as little sediment as possible from the gully net. This can be accomplished by applying water-control practices mainly to noneroding areas. Structures should not be built in actively eroding areas. Sediment trapped in water control structures decreases their useful life and prolongs the time required for restoration of valley floors.

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Effects of Surface Soil Treatments on Soil, Water, and Vegetation in Utah's East Desert Area

by
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An Abstract

The East Desert area of Utah is a prime source of sediment to the upper Colorado River Basin. This area, which is in the Salt Desert Shrub zone, is part of the more than 50,000,000 acres of "frail" lands in the western U.S. Much has been said about the importance of the Salt Desert Shrub vegetation zone as a winter range and its economic contribution to the livestock industry. Very little has been mentioned however, about the watershed relations of such lands. The area occupied by the "frail" lands of the upper Colorado River produces only about 5 percent of the water supply of the river, but more than 44 percent of the sediment load as measured at Lee's Ferry.

Because of the contribution of the area to the total sediment load of the upper Colorado River and the subsequent effect on existing and proposed reservoirs, the Bureau of Reclamation, working with the Bureau of Land Management, initiated certain land treatment practices designed to reduce the damaging silt-laden flows from the area and to promote vegetation production. The program was initiated on the area during the mid 1950's. The area reported on in this paper lies between the Bookcliffs on the north and the Colorado River on the south, the Utah-Colorado state line on the east and Crescent Junction, Utah on the west. Vegetation is very sparse, averaging about 4 - 5 percent total cover. The soils are derived from Mancos shale and sandstone and are highly unstable. Erosion is very pronounced, as indicated above, and flash floods occur quite often. The treatments applied to the more active

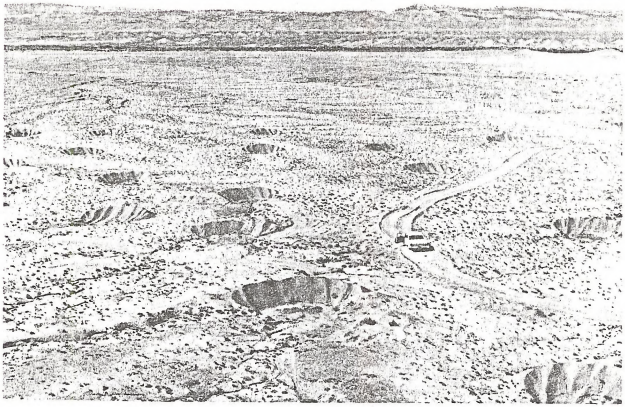


Figure 1. Surface treatments in the study area.

sediment source areas were contour furrows, and gully plugs or check dams (Fig. 1). Several thousand acres have been treated up to the present time.

During 1965 the agencies involved requested the Utah Agricultural Experiment Station to evaluate the effects of the soil surface treatments on the soil, water, and vegetation resources of the area. An intensive program of soil moisture, erosion and sedimentation, and vegetation sampling was undertaken, starting in July, 1965. The results reported are for one fiscal year and are entirely preliminary.

Soil Moisture

Soil moisture has been sampled both gravimetrically and with the neutron probe. The sampling scheme is designed to determine the distribution of moisture around the surface treatments following storm events and throughout the year. Soil moisture is sampled to depths of 24 inches gravimetrically and to 60 inches with the neutron probe.

The data obtained thus far indicate very little penetration of moisture into the surrounding soil from the treatments (Figs. 2 and 3). The implication is that most of the moisture trapped in the furrows and gully plugs is evaporated rather than infiltrated. From the standpoint of sediment reduction this is highly desireable, but is not conducive to increased vegetation production because of the loss of the moisture to the atmosphere. An area comparison indicated that significantly more soil moisture was present in the 0 - 6 inch depth of soil in the treated area than in a comparable untreated area; however the situation was reversed at the 12 and 18 inch depths. The data indicate there is a general tendency for the soil moisture to decrease with the increasing soil depth. Also, little moisture recharge occurs below 18 inches depth.

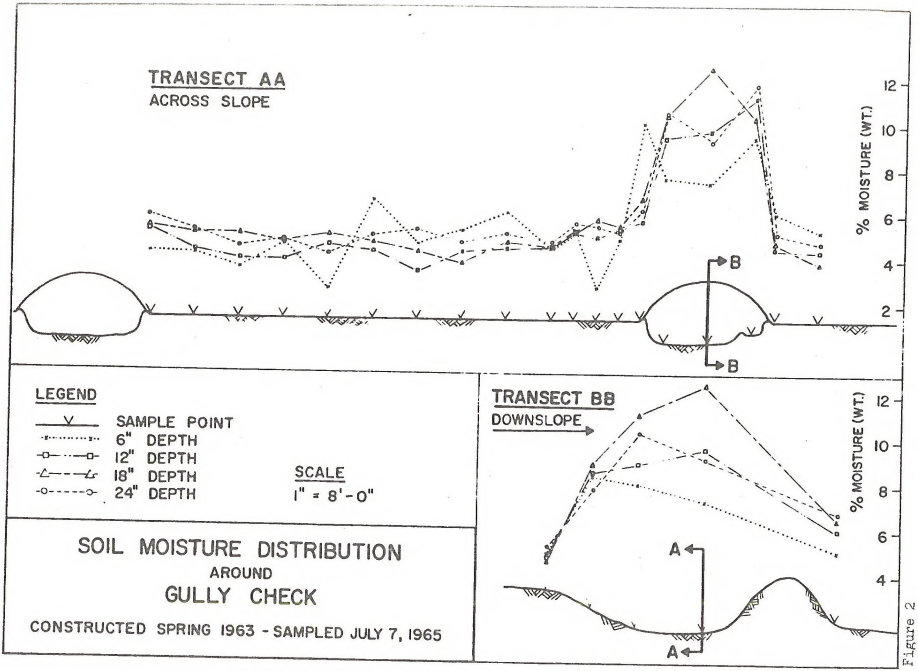
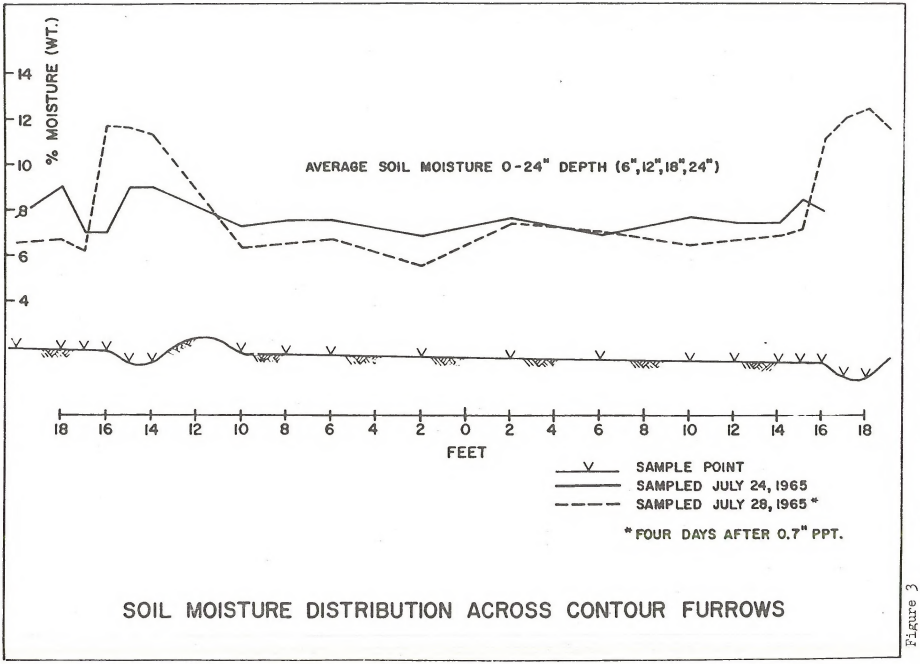

TRANSECT AA
ACROSS SLOPE
% MOISTURE (WT.)
12
10
8
6
4
2
B
B
LEGEND
SAMPLE POINT
6" DEPTH
12" DEPTH
18" DEPTH
24" DEPTH
SCALE
1" = 8'-0"
TRANSECT BB
DOWNSLOPE
% MOISTURE (WT.)
12
10
8
6
4
A
A
SOIL MOISTURE DISTRIBUTION
AROUND
GULLY CHECK
CONSTRUCTED SPRING 1963 - SAMPLED JULY 7, 1965

Figure 2



SOIL MOISTURE DISTRIBUTION ACROSS CONTOUR FURROWS

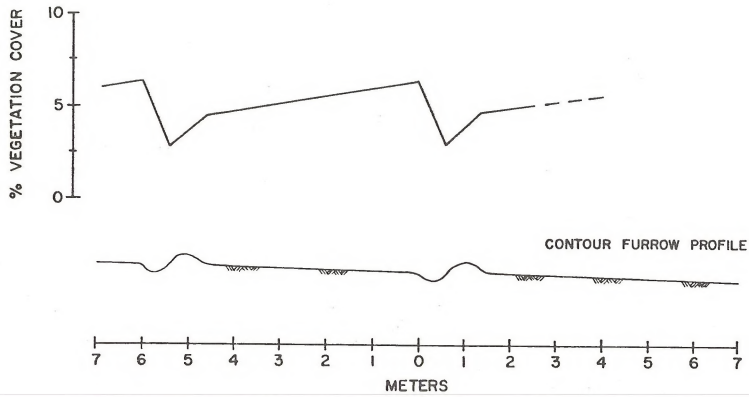
Figure 3

Erosion and Sedimentation

Measurements of the erosion and sedimentation have been taken throughout the study area by means of erosion stakes (point measurements) and erosion transects (6 feet long, 18 measurement points). Preliminary erosion stake data indicate that during the period September - December, 1965 an average reduction in soil surface elevation of .568 inches occurred in areas not affected by the treatments. Precipitation during this period amounted to approximately 3 inches. The average depth of sediment accumulated in the gully plugs during this same period was 2.215 inches. It appears that the surface structures are quite effective in terms of catching and holding surface runoff and sediment if they are properly constructed and located. Further analyses will determine the relationship between such physical factors as slope, vegetation cover, aspect, slope position, etc. on erosion and sedimentation rates.

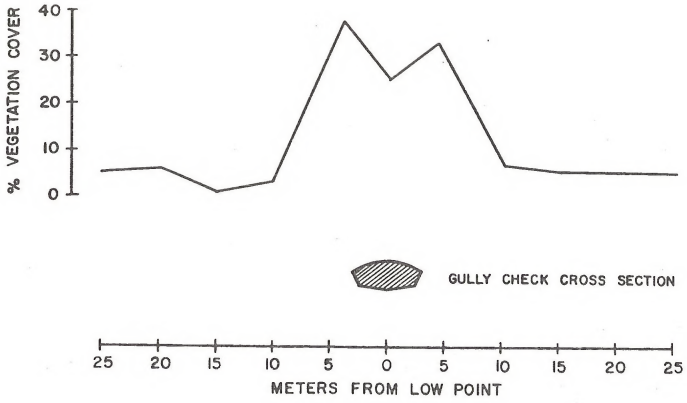
Vegetation

Intensive vegetation sampling has also been underway in the study area. Vegetation measurements include canopy coverage, density, phenology, and production. Also, rocks, litter, and bare ground are measured along with the vegetation. The measurements are made randomly for area comparisons and stratified by treatments for specific treatment effects. Thus far, the data indicate vegetation production is increased immediately around the treatments but the area of influence does not extend much beyond the treatment edge (Figs. 4, 5 and 6). This vegetative response agrees rather well with the soil moisture distribution patterns indicated in Figures 2 and 3. Total vegetative cover, in areas that have been sampled, ranges from 3.5 - 6.0 percent. Bare ground accounts for approximately 85 - 95 percent of the area (litter and rock comprise the remainder).



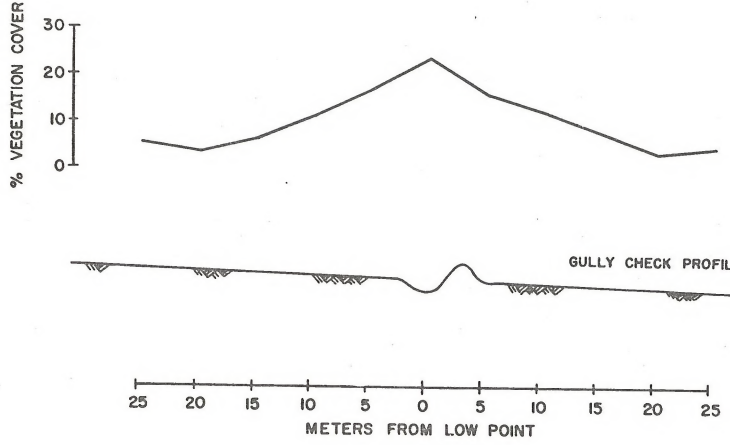
VEGETATION COVER
RELATIVE TO
CONTOUR FURROW
- COMPOSITE SAMPLE -

Figure 4



VEGETATION COVER
RELATIVE TO
GULLY CHECK CROSS SECTION
- COMPOSITE OF 30 SAMPLES -

Figure 5



VEGETATION COVER
RELATIVE TO
GULLY CHECK PROFILE
- COMPOSITE OF 30 SAMPLES -

Figure 6

The information presented in this paper is tentative at best and is furnished mainly to inform participants of the symposium about the nature and status of a watershed project being conducted in the Salt Desert Shrub zone.

THE EFFECT OF SEASON AND INTENSITY OF DEFOLIATION ON SALT DESERT SHRUB RANGES

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Most of the salt-desert shrub ranges in the Intermountain area are used for winter grazing by livestock. Some are used yearlong by cattle and many are grazed until late spring by both cattle and sheep.

Salt-desert shrub species exist under adverse conditions including arid climates and high salt concentrations in the soil. It is common knowledge that these forage species are susceptible to permanent damage from heavy use during various seasons of the year.

In order to determine the physiological and chemical responses of salt-desert shrub species to various seasons and intensities of use, a study was initiated involving 3 separate investigations. All three investigations included 7 dominant species. The first investigation was conducted from 1955 to 1958, the second from 1958-1961, and the third was initiated in 1962 and is still in progress, (1966). This latter investigation will be terminated in 1968 or 1969.

During the first investigation, the plants were harvested at 3 intensities (25, 50, and 75 percent) at each of 4 seasons which included: fall (Nov. 1), early winter (Jan. 1), late winter (March 1), and spring when about 20 percent of their annual growth was produced (May 1).

During the second investigation, the 3 intensities were raised to 30, 60 and 90 percent and the 4 seasons were winter (Jan. 1), early spring (April 1), late spring (May 1), and winter and again in late spring.

In the first investigation spring harvesting was the most detrimental and there was no significant difference among fall, early winter and late winter periods of harvesting.

In the second investigation, defoliation during the winter and again in late spring was most harmful. Late spring harvesting was decidedly more detrimental than early spring. There was no significant difference between winter and early spring harvesting.

Plant vigor decreased with increased intensity of harvesting during all seasons for both investigations. This response to intensity of defoliation was more pronounced for late spring harvesting.

The third investigation which is currently in progress includes 3 intensities (30, 60 and 90 percent) and 4 seasons namely: winter (Jan 1), late spring every year (May 7), late spring alternate years (May 7), and summer (July 1).

This current investigation indicates that annual summer use is more harmful than annual late spring and annual late spring harvesting is more detrimental than annual winter use. Alternate late spring use appears to be slightly more adverse to plant welfare than annual winter use. Again it is demonstrated that vigor of plants decreases with increased intensity of use during all seasons of harvesting. The effect of intensity is more marked during annual

late spring harvesting and still more pronounced during annual summer harvesting.

The physiological responses of the defoliated plants in these investigations suggest that salt-desert ranges are best adapted to winter grazing. If not used over about 60 percent during this period, November 1 to April 1, would have about twice the grazing capacity as if grazed in the late spring or summer when the plants cannot tolerate more than 25 to 30 percent annual use.

Salt-desert shrub ranges like other range types produce a higher nutrient level after spring growth starts until dormancy is reached sometime during mid-summer or fall. The nutrients during spring are adequate to meet the requirements for growth and lactation of range livestock. However, it must be remembered that plants during this period will tolerate only light use and thus approximately one-half the grazing capacity must be sacrificed in order to obtain this higher nutrient value.

Studies on foothill ranges of the Intermountain area suggest that more adequate spring ranges can be developed from seeding introduced grasses. This would relieve spring and summer grazing on desert ranges and allow the maintenance of larger and more stable livestock numbers.

WILDLIFE USE OF THE SALT DESERT SHRUB AREAS OF THE GREAT BASIN

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Historical use of the Salt Desert Shrub type in Utah consisted of both wildlife and domestic livestock.

Principal wildlife use of this area was made by antelope. Early explorers recorded that antelope populations were present and in some areas were more abundant than rabbits. However, rabbits could well have been at a low of their population cycle. Nevertheless, this does give credence to the fact that antelope populations were higher than are currently present. Other wildlife use of the desert areas consisted of mourning doves, though little was mentioned about population level.

Livestock use of the Salt Desert Shrub began immediately following the pioneers entering the Salt Lake Valley in 1847. By 1880 there were 599,000 sheep and by 1890 there were 2,150,000 animals. Also by this time there were about 360,000 cattle on Utah ranges. Peak sheep numbers were reached in 1901 when about 2,882,000 sheep were present. Peak cattle numbers came in 1920. This was recorded as 484,000 head.

Uncontrolled grazing occurred on these desert ranges until 1934 when the Taylor Grazing Act was passed. As a result of heavy domestic livestock grazing, vegetative composition changes occurred. In many areas more palatable species such as black sage were eliminated. A

distinct increase of shadscale came about and introduction of Russian thistle and halogeton took place.

The same species of wildlife comprise the present day wildlife use of the Salt Desert Shrub Area in Utah. Principal big game use is antelope. The next important wildlife use is mourning dove. There likewise is a slight overlap of deer and chukar partridge.

I should like to treat each of these uses separately.

Though antelope are present they are sparsely distributed throughout the East and West desert areas of Utah. The estimated total state population is about 1,500 animals and is static. Good fawn crop occurs early but by September, fawn survival is reduced to 30 percent in many herds.

Antelope are more closely associated with the black sage type. This often occurs closely to or in combination with other vegetative types such as shadscale and winterfat. In any event, these vegetative types have one primary characteristic, they are all sparse.

We of the Fish and Game Department have frequently asked the question, "Why do not antelope do better?" Studies have been conducted. Initial work featured a study of predator-prey relationships. Specific studies were made on the impact of coyotes and bobcats. Later work was conducted on eagle predation. Though limited predation did occur, it was not considered sufficient to cause the static condition of Utah antelope herds. Thus a more comprehensive research project was initiated primarily to ascertain limiting factors in antelope production and survival.

This research began in 1960 and continues today at the Desert Range Experiment Station in Southwestern Utah. It has long been speculated that range condition was probably one of the limiting factors of antelope survival. Thus the Desert Range Experiment Station offered an area of optimum range conditions. Since it had been fenced and properly used since about 1934, the range is considered to be in good condition compared to the outside depleted ranges. A captive antelope herd is being studied within a fenced portion of the Desert Range Experiment Station. This study is a joint effort between the Utah State Department of Fish and Game and the United States Forest Service Intermountain Forest and Range Experiment Station.

Objectives of the study include:

1. To determine the effect of range condition on antelope productivity and survival.
2. To determine antelope forage preference and consumption.
3. To determine mortality factors which may be limiting herd productivity and survival.
4. To compare the effects of use by antelope and sheep on black sagebrush.
5. To determine water consumption.
6. To determine the relationship of plant moisture content and forage consumption.
7. To determine browse preference of antelope.

Some of the preliminary results of the antelope study are reviewed here. In connection with browse preference a "cafeteria set-up" was made.[1/] Antelope were confined to a 40-acre enclosure inside which vegetation consisted of shadscale, winterfat, Indian ricegrass, and dry Russian thistle. Antelope were familiar with the above species for two and one-half months prior to the experiment.

Racks were constructed to hold plants offered to the antelope. Plants were weighed prior to offering and all species which were utilized were reweighed after use. Each morning additional plants were added. In all, 16 species of browse plants were offered.

Five species comprised almost 99 percent of the diet. Big sage, black sage, and juniper were the most important species utilized. Big sage comprised over one half of the diet. Eight other species contributed slightly more than 1 percent of total forage consumed. Of particular interest is that of the consumption of big sage and black sage; black sage is generally considered more palatable to livestock, but this research showed as it did with deer, that big sage was more palatable. Even with such species offered as Cliffrose, little leaf mahogany and fourwing saltbush, both species of sagebrush were preferred.

1/ Arthur D. Smith, Donald M. Beale and Dean D. Doell, Browse Preferences of Pronghorn Antelope in Southwestern Utah. Transactions N. Amer. Wildlife and Natural Resources Conference 1965.

I would like to discuss some of the other phases of this study. In connection with fawn production, 29 fawns were born in the experimental area in the Spring of 1964. These were dropped by 16 mature does. Thus a ratio of 100 does per 181 fawns existed. The 1964 year was a dry year. On an adjacent open range, the doe fawn ratio was 100: 41 in June. Eight fawns were marked and tagged inside the exclosure and the ninth one had a radio placed on it.

In the spring of 1965 which was an excellent precipitation year, 20 fawns were dropped by 16 mature does in the experimental area. On the outside range 8 mature does produced 12 fawns.

Fawn mortality and survival was noted for the two years. In 1964, 24 out of the original 29 fawns were alive in the experimental area by July 1. Losses included one fawn rejected, three of the tagged animals never showed up and were believed abandoned, and the one fawn equipped with a radio disappeared after three days. In all, however, there was a higher doe to fawn ratio inside compared to the outside range.

In 1965, which was an exceptionally good forage production year, poorer fawn survival was present on the experimental area compared to the outside poorer range. Only five of the 20 fawns survived to December in the experimental area. Eight mature does produced 12 fawns which all survived to December on the outside range. The mortality was not confined to fawns. Of the 10 dead carcasses found in the experimental area, five were fawns, four were adult does, and one was an adult buck.

Other phases of the research included forage preference and consumption. Black sage formed the biggest part of the antelope year-round diet during the 1964 dry year. Early spring use was heavy on Poa secunda up until seed formation and antelope then showed a preference to forbs. By the first of May, use of grass was very light and was restricted to use of the seedheads. During June, forb consumption was 75 percent and black sage was 25 percent. By August the vegetation was dry and precipitation was well below normal. Antelope in the experimental area then relied more on black sage. Before sheep use in the fall, antelope had used black sage to the extent of 23.4 percent. Antelope use of black sage by mid-December of 1964 was 34.7 percent.

Stomach samples were collected during the antelope hunt in August of 1963. This would be on the outside range. Table 1 shows the plant composition determined from rumen samples.

Table 1. Average percent composition of antelope rumen samples collected during the hunting season of 1963.

Species	1963 (4 samples)
Shrubs:	
Artemisia nova	52
Juniperus osteosperma	T*
Prunus fasciculatus	4
Cowania stansburiana	1
Chrysothamnus spp.	1
Forbs:	
Chenopodium spp.	1
Eriogonum spp.	3
Euphorbia ocellata	10
Machaeranthera canescens	T
Opuntia spp.	2
Salsola Kali	2
Solanum triflorum	18
Sphaeralcea spp.	5
Grass	T

*T = trace

During the wet year of 1965 antelope in the experimental area utilized forbs more and black sage less. This probably was due to the abundance of succulent forbs. Table 2 shows forage production and utilization during summer and fall of 1965.

Table 2. Herbage production and utilization by antelope in the shadscale-black sagebrush-grass type during summer and fall of 1965. Data from 180 plots.

	Herbage (pounds/acre) dry weight	Utilization (Present)	Percent of diet
Shrubs:			
Artemisia nova	15.9	5.1	23.4
Artemisia spinescens	4.7		
Atriplex confertifolia	61.6		
Brickellia longifolius	0.1		
Chrysothamnus spp.	13.6		
Ephedra nevadensis	9.8	1.6	4.6
Eurotia lanata	31.2		
Gutierrezia sarothrae	23.2		
Kochia vestita	0.1		
Polygala acanthoclada	0.2		
Prunus fasciculata	1.5		
Tetradymia spinosa	0.8		
Forbs:			
Aplopappus nuttallii	0.5	4.3	0.9
Aster spp.	0.2		
Astragalus spp.			
Chaenactis macrantha	0.6 1/		
Cruciferae			
Cryptantha spp.	2.1	0.6	0.3
Enceliopsis nudicaulis	0.1		
Erigeron concinnus	0.5	29.2	4.6
Eriogonum spp.	5.3	2.4	3.0
Euphorbia spp.	0.1		
Halogeton glomeratus	19.4		
Hymenopappus lugens	0.2	12.5	0.6
Lappula occidentalis	1.5		
Lepidum scopulorum	1.2	0.8	0.4
Linum lewisii	0.3 1/	11.2	1.3
Oenothera canescens	0.4	5.3	0.7
Penstemon spp.	0.6		
Phacelia crenulata	1.1 1/		
Phlox caespitosa	0.1		
Salsola kali	0.3		
Sphaeralcea spp.	9.4	18.3	59.8
Townsendia florifer	0.3	0.7	0.1
Grasses:			
Aristida spp.	0.3		
Bouteloua gracilis	9.8		
Bromus tectorum	0.8	1.4	0.3
Hilaria jamesii	23.5		
Oryzopsis hymenoides	48.3		
Sitanion hystrix	5.5		
Sporobolus airoides	21.7		
Stipa comata	1.0		

1/ Mostly new seedlings

Forbs were not as abundant outside the experimental area in 1965. Sphaeralcea was present but Russian thistle and eriognum were abundant. These forbs, along with black sage and fourwing saltbush, formed the major portion of the antelope diet in early spring. Late summer storms produced forbs such as euphorbia. These formed a major part of the diet for several weeks in late summer. Early frost in September destroyed forbs and antelope moved back to an area where more black sage was present.

Precipitation records for the past 30 years show the average annual precipitation to be six inches at the Desert Experiment Station.

Another portion of the study consisted of measuring water consumption by antelope. Little free water was used by antelope in 1962, 1963, and 1964 in the experimental area. This probably reflects the availability of succulent forage. Very little free water was taken from April through June and mid-August to November of 1965. In time when vegetation is dry and antelope are dependent upon water, they use about one gallon per antelope per day.

I would like to briefly discuss the second primary wildlife use of the Salt Desert Shrub Area. This use is that of the mourning dove. It is the principal upland game bird species in this area and is distributed throughout the desert areas where free water is available. Doves nest considerable distance from water but water is a very vital necessity for their existence in this desert habitat.

Dove production is tremendous in this type throughout the Great Basin Area. This production not only benefits the local states such as Utah and Nevada, but more of this crop migrates to such states as Arizona and Southern California and even Mexico. By the time our hunting season opens on the earliest possible date by International Law (Sept. 1,) the bulk of doves have migrated southward.

The following is presented so that one might obtain an insight into the magnitude of dove hunting:

	1961	1962	1963	1964	1965
Mourning dove hunters	15,192	14,600	18,258	19,829	18,710
Mourning dove harvest	128,001	145,088	162,769	193,538	164,477
Birds per hunter	8.24	9.89	8.91	9.78	8.69
Birds per hunter-day		4.23	4.02	3.73	3.36

The optimistic feature about dove hunting is that we still have a vast potential in hunting area and birds to accomodate more hunters.

Other wildlife use of the Desert Area are noted; mule deer and chukar partridge are on the periphery of this type. Mule deer use is confined to the winter period when deer move to the foothill areas of the desert mountains. Generally chukars are associated with the edge of the Salt Desert Shrub Type by virtue of the distribution of free water.

Other uses include songbirds, blacktail and cottontail rabbits, kit fox, coyote, and bobcat.

One remaining phase I should like to treat is that of habitat improvement. Our efforts have been restricted solely to water development. This has been a joint effort with the BLM. Water developments are generally placed on the lower foothill areas of the desert

mountains so antelope, chukar, partridge, and mourning dove can all use. If water were placed too far out in the valley, this could eliminate chukar use.

We initially utilized a plastic type guzzler with 1,000-gallon capacity. This is suitable for birds alone but because of low capacity and high evaporation losses, it has serious limitations for antelope use. Thus we now bury a 2,000-gallon tank for storage and use the same type collecting apron made out of corrugated steel. The rain falls on the apron and is collected and drained into a buried tank where it is piped to a small drinking fountain containing a float valve. The use of the latter water development has allowed a double increase of stored water and has cut the cost of the water development in half. The latter type costs approximately $250 each using surplus storage tanks.

What is the future of wildlife use of the Salt Desert Shrub type? We are optimistic but realize it is strictly based on how well the BLM manages these ranges. We are dubious that these desert ranges can sustain the intensity of livestock use they are currently subjected to. It is the harshest environment - it receives the least precipitation (about 6 inches annually) - yet, proportionately it is subjected to the highest intensity of grazing.

Some of the ranges still are utilized year round by livestock-sheep in the winter and cattle in the summer.

Another poor practice is that of allowing the feeding of protein supplement, particularly on winter sheep ranges. This has had a marked deleterious effect, particularly on the black sage type.

It would appear that, with so little precipitation, these desert ranges will not be restored to their maximum productivity and optimum vegetative composition until some system of deferred rotation grazing is initiated.

There is little hope that we can maintain antelope population in this vegetative type until livestock grazing practices are adjusted to encourage substantial range improvement in this harsh environment. This would allow re-establishment of such palatable species as black sage and other palatable plants over much of the area of their former range rather than sustaining a high portion of less desirable and undesirable plants.

In the meantime, we feel the cooperative water development program should continue and be placed so as to benefit all of the wildlife species rather than for a single use.

We all have a tremendous investment in the Salt Desert Shrub Area. It is an important link in the economy of the livestock industry and forms an important area for wildlife use. We have great confidence in the ability of the BLM to bring these ranges back to their full potential.

MATERIAL PREPARED FOR
SALT DESERT SHRUB SYMPOSIUM
PRESENTATION

KIETH E. SEVERSON
University of Wyoming

The information used in this discussion was obtained in a cooperative study initiated by the Bureau of Land Management, the Wyoming Game and Fish Department, and the Plant Science Division of the University of Wyoming. The primary objectives of the study were to determine the degree of overlap in use of native vegetation and to determine grazing capacities of pronghorn antelope and domestic range sheep.

The study area is located in the Red Desert region in the south central part of Wyoming north of Wamsutter. The greater portion of the observations were taken from a pasture system which was designed and constructed by the Bureau of Land Management and consists of six pastures; 2 of 120 acres, stocked with antelope; 2 of 120 acres, stocked with sheep; and 2 of 240 acres, stocked with both antelope and sheep. The pastures are located in a homogeneous big sagebrush community.

The major species in the study area are; big sagebrush, Artemisia tridentata; Douglas rabbitbrush, Chrysothamnus viscidiflorus var. pumilis; thickspike wheatgrass, Agropyron dasystachyum; needleandthread, Stipa comata; Indian ricegrass, Oryzopsis hymenoides; squirreltail, Sitanion hystrix; winterfat, Eurotia lanata; Sandberg bluegrass, Poa secunda and needleleaf sedge, Carex obtusa.

The methods and procedures used were all based on standard range analysis methods. Percent compressed crown cover and percent utilization by weight of the plant species were estimated from plots 1' x 10' in size.

Ninety of the plots were analyzed during each sample period. Production was determined for all species except sagebrush by clipping 96 caged plots, 2' x 4' in size. Sagebrush production was obtained by clipping 15 plots, 4" wide x 50' long, in an exclosure adjacent to the pastures. The datum on sagebrush production from the exclosure was applied to all pastures. Sagebrush utilization was estimated by examining 150 plants in each pasture. All sample numbers were obtained by statistical analysis and all weights given are oven dried weights.

Under the direction of the Wyoming Game and Fish Commission two antelope and two sheep were collected for rumen samples each month. Other data collected at the same time included body, viscera and organ weights, jaws for age determinations and information on internal parasites.

Forage production varied significantly between 1964 and 1965 (Table 1). The most significant increase was noted in the annual production of big sagebrush - from 147 lbs/acre to 266.7 lbs/acre. All species except Douglas rabbitbrush and winterfat demonstrated some increase. The difference in annual production between 1964 and 1965 can be explained by variations in climate. Annual precipitation has been increasing every year since 1962 when $4\frac{1}{2}$" were recorded.

Five inches fell in 1963, 5½" in 1964, and through October of 1965, 6.7" were recorded. The long-term average for the Wamsutter station is 5.47." I would also like to call your attention to the forb production for this area. The minor contribution by forbs to the vegetation is fairly characteristic of the entire desert, except in disturbed areas where Russian thistle and halogeton are found. This is the reason that the information we have obtained in Wyoming doesn't even remotely resemble that collected in Texas by Buechner or Russells studies in New Mexico. In both of these areas forbs were predominant in both the flora and antelope diets. The forb category includes one species each of Arabis, Penstemon, Astragalus, Allium, Cryptantha, and Gayophytum. Of these only Arabis was utilized.

TABLE 1

PRODUCTION*

Lbs./Acre - Oven Dried

	1964	1965
Big sagebrush	147.0	266.7
Douglas rabbitbrush	89.4	88.7
Thickspike wheatgrass	51.6	57.2
Needleandthread grass	19.3	21.1
Indian ricegrass	14.5	19.2
Squirreltail grass	13.0	14.9
Winterfat	10.0	6.7
Sandberg bluegrass	3.6	7.7
Needleleaf sedge	3.1	8.1
Forbs	t	2.6
Total	351.5	492.9

*Editorial reproduction of photo slide

Utilization figures are given in pounds consumed per acre over a particular season - which is measured in animal days use. Table 2 compares data gathered in the summer of 1964 with that collected over the same period in 1965. The excellent replication demonstrated by thickspike wheatgrass is, at best, unusual. It does, however, demonstrate the trend that will become obvious after examining the entire table - and that is the preference for grasses by sheep as compared to antelope. The shrub trend is indicated by Douglas rabbitbrush which is preferred more by antelope than by sheep.

TABLE 2

UTILIZATION - RANGE ANALYSIS*

Pounds Consumed Per Acre - 1965

Pastures	Combined	Antelope	Sheep
Douglas rabbitbrush	12.8	20.2	2.0
Big sagebrush	4.6	9.6	1.5
Western wheatgrass	2.5	0.3	2.7
Indian ricegrass	4.4	0.1	10.6
Needleandthread	5.2	T	10.0
Sandberg bluegrass	1.4	0.1	1.5
Squirreltail grass	0.2	T	1.3
Obtuse sedge	T	T	0.0
Winterfat	1.5	0.5	2.9
lbs. used/acre	32.6	36.8	32.5

*Editorial reproduction of photo slide.

In Table 3, do not confuse the "t's" with "ones." Indian ricegrass and needleandthread are taken infrequently by antelope, but are the two most important species in the sheep diet. Needleandthread appears to be more preferable than Indian ricegrass. There is some difference in sheep use of these two species from 1964 to 1965, notably a decrease in use of needleandthread and increased use of Indian ricegrass. I will discuss the possible reasons for these a little later. Sandberg bluegrass follows the same trend - that is, use to a greater extent by sheep. However, both animal species tend to use this plant heavily in the spring because it is the first species to exhibit green growth, but sheep utilize it further into summer. Winterfat, in the summer, is used infrequently by sheep and not at all by antelope. Big sagebrush, another important species in the antelope diet is utilized to a rather small extent in the summer, but still ranks number 2. Sagebrush use by sheep is quite variable.

This difference, as well as all other major differences between 1964 and 1965 probably could be explained in two ways; (1) either as sampling error or (2) through differences in the growing seasons. Big sagebrush did present a problem when it came to determining use. The growth form of this plant is, generally speaking, very low, scrubby and with very tight, knotty leader groups. We tried measuring use quantitatively by tagging twigs and weighing browsed and unbrowsed leader groups but the time involved and the sample numbers necessary made these methods infeasible, so we ended up using ocular estimates

which, of course, are subject to human bias. However, the antelope use was well replicated between years. Also, the number of sagebrush plants examined in each pasture was increased from 100 to 150 for the second year, which would facilitate any determination of use if any were present.

The second reason for the differences is the length of growing seasons. Green growth was available from the end of April to mid-July in 1964 and from the end of April to mid-August in 1965, or about one month longer. Sagebrush use has been detected on the pastures in the November transects run this year so it appears that it is not used by sheep until the grasses have died back. The next species, squirreltail grass, is also more important to sheep than to antelope and again there is a substantial difference from 1964 to 1965 in the sheep diet. Needleleaf sedge is fairly common in all pastures but utilization of this species is minimal by both animals. The total lbs/acre used by antelope in 1964 is based on use for 833 animal days; in 1965, 1041 animal days. This comes out to 1.6 and 1.4 lbs. used/animal/day, for the two summers. The total pounds used by sheep in 1964 is for 750 animal days as compared to 864 animal days for 1965. This comes out to 2.1 and 1.4 lbs/animal/day.

TABLE 3

UTILIZATION*

	Summer 1964		Summer 1965	
	Antelope	Sheep	Antelope	Sheep
Thickspike wheatgrass	0.1	1.8	0.1	1.8
Douglas rabbitbrush	9.5	0.2	10.1	0.3
Indian ricegrass	t	1.0	0.1	2.7
Needleandthread grass	t	6.6	-	3.7
Sandberg bluegrass	t	0.3	t	0.9
Winterfat	-	t	-	0.1
Big sagebrush	1.2	2.4	1.5	-
Squirreltail grass	0.1	1.3	-	0.4
Needleleaf sedge	t	t	t	-
Lbs. Used/Acre	11.1	13.6	11.8	9.9

*Editorial reproduction of photo slides

The winter column on Table 4 should be corrected to read fall and winter, 1964, and the total 1964 column represents averages for the entire year. Sheep data are absent from the fall and winter column and also, of course, from the summary column, for the year 1964 because of the severity of that winter. Enough sheep were lost from these pastures to render the data invalid and weather conditions made restocking completely infeasible.

As for antelope, thickspike wheatgrass use was absent in winter and contributed very little to the yearly total. Douglas rabbitbrush use decreased from summer to winter but was still very important. Most of the utilization shown in the fall-winter column was from September to mid-November, after which it was pretty well covered by snow. In the yearly total this is the most important species. Indian ricegrass and needleandthread use was not found in winter and both were unimportant as to their contribution to the animal's diet. Sandberg bluegrass follows this same grass trend in the antelope foods and is only important early in the year. Winterfat demonstrated a notable increase over summer but, like rabbitbrush, its use was limited to fall, as it was covered by snow from November on. Big sagebrush was the most important species in the antelope diet in the winter, primarily, I suspect, because of availability. The snow depths ran from 6 inches to 4 feet in drifts last winter and sagebrush was the only visible species on some areas. Most of the use indicated in the winter column of this chart was after mid-November. Squirreltail grass was relatively little used. No use was found on needleleaf sedge

during the winter and this plant also contributed little to the final total.

This year, the fall data was separated from the winter data and, although I haven't presented this in Table 4, I have used the 1965 data to arrive at conclusions as to when the species listed here were used. The total lbs/acre used in winter is based on 1544 animal days and calculates to 1.7 lbs. used/animal/day. The yearly summary is based on 2377 animal days and comes out to 1.8 lbs. used/animal/day. The data from the combination pastures has not been presented here but utilization on these pastures does demonstrate intermediate values when compared to the other pastures.

TABLE 4

UTILIZATION *

	Winter 1964		Total 1964	
	Antelope	Sheep	Antelope	Sheep
	-	no data	-	no data
Thickspike wheatgrass			.2	
Douglas rabbitbrush	10.4		20.1	
Indian ricegrass	-		.1	
Needleandthread grass	-		t	
Sandberg bluegrass	-		t	
Winterfat	.8		.9	
Big sagebrush	11.6		13.2	
Squirreltail grass	-		.1	
Needleleaf sedge	-		.1	
lbs. used/acre	22.8		34.7	

*Editorial reproduction of photo slides.

Closely controlled feeding trials were also conducted with penned animals (Table 5). Here, several animals were given various combinations of different plant types in excess of what they would need and the following day, that remaining was weighed, subtracted from that given, and this, divided by the number of animals used. Again, all weights are based on oven dried samples. Eighteen days of data were collected in this manner for antelope and compared to data collected from the pastures. Each of the ten observations from the pastures is an average derived from one season's use. For example, antelope averages 1.7 lbs/day during the fall and winter. This explains the smaller range noted in the pasture data. When the two means were compared, using a simple t-test, no significant difference was noted.

TABLE 5

ANTELOPE*

Daily Consumption

Feeding Trials	Pastures
18 Observations	10 Observations
Range 0.5 - 2.6 Lbs/Day	Range 1.3 - 1.8 Lbs/Day
Average 1.5 Lbs/Day	Average 1.7 Lbs/Day

*Editorial reproduction of photo slides

Table 6 shows a significant difference in daily consumption by sheep. Sheep consumption in feeding trials averaged almost twice as much as was found by the range analysis methods. I think that this can be explained by observing the feeding habits of sheep. They appear to use as much forage as possible when it is offered to them in such a manner that they didn't have to work to obtain it. In other words, the time spent in seeking preferred plants on pastures is used in eating when feeding from a trough. Palatability may also influence this; some alfalfa was used in the feeding trials along with native forage - however, the largest daily consumption found (4.4 lbs/day) was on native hay. Because the sheep in the pastures were feeding primarily on grasses, some utilization may have been observed by regrowth, which could help account for the lower figure reached through range analysis methods.

TABLE 6

SHEEP*

Daily Consumption

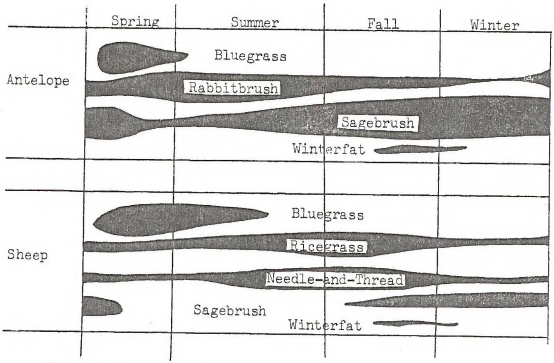
Feeding Trials	Pastures
12 Observations	6 Observations
Range 1.7 - 4.4 Lbs/Day	Range 1.0 - 2.3 Lbs/Day
Average 2.9 Lbs/Day	Average 1/5 Lbs/Day

* Editorial reproduction of photo slides

Table 7 is presented as a summary of the food habits over a year. It was made up in a qualitative sense from data collected by range sampling methods and stomach sample analysis. Sandberg bluegrass, as mentioned before, was taken quite readily in early spring by both antelope and sheep because it was the first species to initiate spring growth and for a period of 10-14 days it is the only green plant in the pastures. As soon as Douglas rabbitbrush starts to grow, antelope start to use it, and it remains the species most used by antelope from late spring to mid-summer. As late summer - early fall approaches, rabbitbrush either decreases in palatability or sagebrush increases, but whichever, there is a notable trend in increased sagebrush use that reaches a peak in winter - one of the reasons for this is availability governed by snow depth. The narrow line for rabbitbrush in winter represents limited availability rather than a drastic decrease in palatability. Winterfat is not really used by either antelope or sheep until late fall and its use again, as with rabbitbrush, is terminated by decreased availability. Grass use by antelope, with the exception of bluegrass, could be represented by a very thin line for the entire year. Sheep went to Indian ricegrass and needleandthread as soon as these species started to grow and they were utilized quite heavily until availability was limited by snow depth. Use was less on these species in the early spring when they were seeking the green bluegrass. Some sagebrush use was noted when the grasses dried up and this use increased through the

TABLE 7

SEASONAL PREFERENCE *



*Editorial reproduction of photo slide

winter, again, because of availability, not palatability. Douglas rabbitbrush, thickspike wheatgrass, and squirreltail grass use by sheep could be indicated by rather narrow lines for the whole year.

There isn't too much that can be said about the feeding habits of animals that hasn't already been noted in previous studies. Antelope move about much more than sheep while feeding, covering about 1½ times the distance in an equal period of time. Antelope are much less gregarious than are sheep. From early spring to late August they remain well distributed over the pastures as singles or in groups of 2 to 3. Also, they have no apparent pattern to their daily movements, they don't play follow the leader like sheep do. Antelope act quite independently, even when found in groups. The pronghorn is also a very delicate feeder, they take less of each plant grazed than a sheep will. This is so common, especially on sagebrush, that it becomes very difficult to determine utilization. Sheep, on the other hand, tend to be much more gregarious. Generally speaking, when one is feeding all are feeding, and so on. Sheep also feed, primarily, early and late in the day, especially in the summer. Antelope, apparently less affected by heat, feed on and off all day.

It can be concluded from the preceding information that there is little competition between pronghorn antelope and domestic sheep for range forage in this particular area. The two major species in the antelope diet are big sagebrush and Douglas rabbitbrush as compared to needleandthread and Indian ricegrass in the sheep diet.

There is some overlap in use of winterfat, Sandberg bluegrass, and big sagebrush. However, two of these species, Sandberg bluegrass and winterfat, contribute so little to the annual production for the area that they could be designated as sacrifice species if need be. Also, both Sandberg bluegrass and big sagebrush have wide ecological tolerances, both are common increasers in this area. The only notable overlap is with big sagebrush, but again, this probably isn't critical because the basic definition of competition states that the resource for which two organisms are competing must be in short supply, but, believe me, sagebrush in Wyoming's Red Desert can be called anything, except "in short supply."

EXPERIENCE IN IMPROVING SALT DESERT SHRUB RANGE BY ARTIFICIAL PLANTING

A. Perry Plummer
Intermountain Forest and Range Experiment Station
August 2, 1966

My experience in attempting to find approaches and plants for successfully improving salt desert ranges by seeding goes back more than 25 years. As a result of considerable effort in this broad type in conjunction with other assignments, I must frankly confess that material improvement of these ranges with less than 8 inches of precipitation involves approaches largely to be discovered. Bleak (1965) and coauthors have reviewed this subject recently. I believe they substantially agree with most of the conclusions I present. Where precipitation is more than 8 inches, we now know that a great deal can be done to improve depleted ranges, including those that may be classified as salt desert shrub ranges (Plummer et al. 1955). However, we would probably still have to say that success is somewhat tenuous where annual average precipitation is less than 10 inches, and particularly when not much more than 9 inches, or slightly less. Inclinations of range managers is to conclude, "do research for artificially improving ranges where we know there is opportunity for success--i.e. in the areas of better precipitation. By creating more forage on these lands with higher precipitation, we can reduce the grazing load on salt desert ranges and then provide the necessary protection and management to get the desired improvement."

No doubt, there is considerable merit in this sweeping conclusion if one overlooks the pressing need for winter range, and probably the fact that protection and management cannot always be depended on for full

recovery. Artificial approaches are required for some of these arid ranges. Personally, I must respect the demanding call for information that will lead to improvement of arid ranges in the Intermountain West where 60 million acres could be involved as well as the many million acres in other countries. With the background we have, I believe something substantial can be done. Truly, I would hope I could take a part in some of the forthcoming research that will produce the solid basis for procedure we are seeking for these quite parched lands.

As a result of my assignment in the past few years to a cooperative project with the Utah State Department of Fish and Game in the improvement of big game ranges, I have become much more interested in shrubs as plants for improvement of arid ranges. In this cooperative project, we have been giving particular attention to the juniper-pinyon type because of its importance as winter ranges for big game. As you know, there is some extension of the juniper-pinyon type into the salt desert shrub type. Despite my increased interest in shrubs, I continue to have my former interest in herbaceous plants because they are important everywhere. We must investigate the broadleaf herbs as well as the grasses. But, I must say as a result of this experience, that I am much more impressed than formerly that there is tremendous area where shrubs will prove superior to herbs in the development of a satisfactory cover, and especially on desert ranges. The shrub resource must be fully exploited for this purpose. However, I recognize, as we have found in the juniper-pinyon type, that a balance of shrubs and herbs will be required to meet the goal of a satisfactory cover for the best balanced production of forage for game and livestock as well as for adequate soil

stabilization on these arid ranges. I am highly optimistic despite the fact that I have already alluded to considerable past failure, and will refer to more because I am relating past experiences. But often it is on the basis of much adversity that final success sometimes works out to be best.

Indeed, there have been a great many failures from various types of planting in different places in the arid salt desert shrub type everywhere. However, most of my experience has been in the Great Basin and in the Upper Colorado River Basin. In all, I know I am conservative in reporting that more than 1,000 plantings have been made by private individuals and personnel of various governmental agencies in this type over the past 30 years. I agree that most of them have been done on a "let's see what happens basis."

From a recent review, it appears that some degree of testing has been made with as many as 200 species and species variants. I have to admit to a considerable participation in testing about this many. And, unless there have been some dramatic developments recently, I would say that in total there has been considerably less than 1 percent real success from all types of planting made where the average amount of precipitation is much below 8 inches. But let us understand that this really is not important as long as we are progressing towards an eventual solution. I pointed out that most of these plantings were of experimental nature, although some have been quite large. In many trials, controls and follow-up have not been of the highest standard. But in defense, I say that some of the best application sometimes comes from not too well conceived experimental approach. That we have not been more successful

probably relates to the fact that we have not assiduously made the necessary follow through.

For several years in my early career, I worked under the supervision of the late Dr. George Stewart when he was head of the Range Investigations for the Intermountain Forest and Range Experiment Station. In the spring of 1940, I went to the Desert Experimental Range west of Milford to review the fate of some fairly quite intensive as well as extensive planting trials we had made in the former 4 years. As I was leaving my office in Ogden, George Stewart called and asked that I mail him a note relating the general status of the experimental plantings at the Desert Station before going on further south to review other experimental plantings. I had planned 6 days to complete the observations on the quite numerous plantings at the Desert Station. As it turned out, I was finished in 1½ days. Actually, I had found little to measure or report favorably about. In fact, many of the plantings which had looked good in former years appeared dead. To say the least, I was dejected. On reaching Milford, I stopped and mailed this statement to George Stewart, "Almost complete loss of all plantings, the best that can be said is sad. Sorry."

On my return to headquarters, George Stewart came into my office with his inimatable smile. He had a piece of yellow paper that I quickly recognized as having put in the mailbox at Milford. He laughed outrightly at my concern as he showed me my infamous note. He remarked, "What you found at the desert station was probably to be expected. Even so, the experimental plantings there provide the basis for future research which will result in positive procedure, if we can learn how to take

advantage of our experiences." To say the least, I was overwhelmed by his optimism, especially in view of the very considerable hard effort that I had put into various types of trial plantings over a period of the previous 3 years. Since, however, I have become much more appreciative of this seasoned scientist's statement. It often does take a lot of concerted research in an endeavor of this kind before really simple answers are forthcoming.

In 1950 and 1951, I reviewed with the late Ben Markham of the Bureau of Land Management a large number of plantings in the salt desert shrub type in the Colorado River Basin that he had made or had been associated with the 6 to 15 years previously in his work with this agency. Some of these had been done in the period of the Civilian Conservation Corps under the supervision of my experienced companion. Ben was a good ecologist. In all, we saw nearly 100 sites where some planting at one time or another had been done. Most of these were less than 5 acres in size. Some were very small, but a few were as large as 20 acres. Plantings had been made on virtually every conceivable site one could ask for in the salt desert shrub type. However, with the exception of about four of them, all had been subjected to the permitted grazing by livestock in the general area. Crested wheatgrass and desert wheatgrass[1/] had been the principal species used.

In some places, Ben had planted as many as 40 native species, including broadleaf plants and shrubs, but desert wheatgrass had been the most widely tested. While there had not been close follow-up on

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1/ See attached table for scientific and common names.

most of the plantings for the few years just prior to our review, the notes that Ben displayed often showed good persisting stands on some sites for as long as 3 years after planting. Our tendency was to ascribe the failures to the grazing by livestock, but it was doubtful we could validly do this because there were also failures where there had been protection from livestock. He did say that plantings had been considerably damaged at intervals by small mammals. Certainly, the effects of these animals, especially where they concentrate, should not be overlooked.

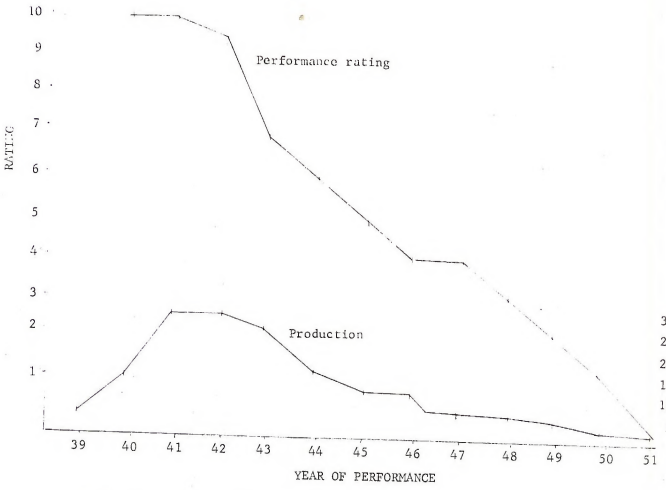
On severe sites, there had at one time been at least fair establishment. But except for one planting of desert wheatgrass at Cisco, Utah, we found very few persisting plants on any of the sites resulting from seeding. At Cisco, on a place that was then in the possession of a Bill Murray where there was an annual average precipitation of 6 inches, we found an outstanding stand of desert wheatgrass on approximately 20 acres. Our spirits skyrocketed because we thought we were seeing an answer. This had been sown with a Planet Junior Garden cultivator in rows spaced 12 to 14 inches apart. The planter was pushed by Mr. Murray in his off hours as a railroad employee. As I recall, the planting which Mr. Murray proudly displayed was then 5 years old and was on highly saline soil that supported a fair growth of Gardner and mat saltbush. This planting had been well protected from livestock grazing. On seeing the area 4 years later, I was appalled to find that very few live plants of the seeded grass remained. Except for a few scattered plants, it could be written off as a failure. However, the dead crowns were the silent evidence of the former excellent stand which had met a fate that perhaps could have been predicted on the basis of past experience.

Graph 1 shows the composite performance and yield of several experimental plantings of desert and crested wheatgrass at the Desert Range Experimental Range made in November, 1937. The average annual precipitation is about 6 inches. As exhibited, good initial stands were obtained. This is usually the case unless the spring and early summer is unusually dry, as similar to what we have experienced in 1966. This graph, with minor variations, depicts what has occurred to a great majority of plantings in the salt desert shrub type where the average annual precipitation is much below 8 inches.

Good initial establishment from fall and winter plantings can generally be expected, especially of the exotic wheatgrasses, when near average annual precipitation is obtained. Late November and December, or even January and February, plantings are preferred to avoid precocious germination if the ground should become moist in a warm period. For the most part, spring seedlings fail to establish unless followed by wet summers. Generally, once good stands were established, they have been productive for at least a few years. Then they deteriorated and essentially disappeared after 10 to 12 years. Catastrophe has struck quicker in a number of instances.

My own experience is that about equally good stands of crested and desert wheatgrasses can be established by direct seeding into chenopod shrubs as where they have been eradicated. Actually, I have seen little to choose between eradicating or not eradicating; although, productivity develops slightly faster where competition has been eliminated. Several comparisons of this kind have been made. I believe this is true of most seeded species whether grasses, forbs, or shrubs. This has been found

Graph 1.--Performance of desert wheatgrass through a 13-year period at the Desert Range Experiment Station - 1939 through 1951.



Performance ratings are based on degree of stand of living plants where 0-none; 1 to 2-very poor; 3 to 4-poor; 5 to 6-fair; 7 to 8-good; 9 to 10-very good, or a full stand.

to be the expectation resulting from several trials in shadscale and winterfat types. If true, this is fortunate because on most salt desert shrub types, it is important to retain the remaining perennials. The objective is mainly to establish desirable plants to improve the cover, but at the same time, retain what is present. In black greasewood types, it may be necessary to break down the top growth so drilling can be accomplished.

Exceptions may be those sites occupied by undesirables, such as the annuals halogeton and cheatgrass brome. Some control of their density may be necessary, but this is outside of my experience. However, we have been able to establish excellent stands in dense growth of Russian thistles, and I had good success in establishing grass in halogeton in the one trial I made. Certainly, I could not call this one experience in halogeton as really representative.

A technique of planting into scalped furrows should prove satisfactory on salt desert ranges heavily infested with competitive annuals, as it has on adjacent cheatgrass ranges with only a little more precipitation. As elsewhere, planting any deeper than ½ inch is not necessary, and merely jeopardizes seedling emergence. In fact, covering to a depth of ¼ inch is ample for small seeds, and usually adequate for larger ones.

Two of the best persisting stands of desert and crested wheatgrass in my acquaintance are direct drillings into fairly full stands of winterfat. One of these was made in the bottom of Wah Wah Valley in November, 1940. Some other species were included in this planting, but the introduced wheatgrasses have persisted as the primary components of

the seeded stands. This planting has been fully protected since planting. The other planting was in the bottom of Pine Valley in 1945, the next valley west from Wah Wah, and the valley in which the Desert Experimental Range is located. Seeding included some Russian wildrye along with the exotic wheatgrasses. This particular planting is interesting because of the excellent persistence and better production of Russian wildrye than the wheatgrasses. There appears to be little to choose between these two wheatgrasses, but in my experience, crested wheatgrass reproduces more aggressively. Annual precipitation at these sites is estimated to be between 6 and 7 inches, or not essentially more than many other places where plantings have failed. However, the soil tends to have better moisture holding qualities than on many of the sites on the higher benches where the losses of these plants have been more complete.

Although both of these plantings have been considerably thinned from the original densities, they appear to starkly refute the conclusion that successful plantings using these exotic wheatgrasses cannot be made on salt desert shrubs, and one ponders the reason for the total losses elsewhere. We conclude, there is much we do not know. Since most of the living population of wheatgrass is from reproduction, we may rationalize that the existing plants on these sites may have resulted from natural selection so remaining plants may be ecotypes, better suited to arid ranges than were the plants from the commercial seed which was grown in Canada and North Dakota. Perhaps this is closer to the truth than we can accept. At any rate, we should look closer at this possibility.

Another test planting involved the use of a number of native shrubs and herbs along with crested and desert wheatgrass. This was made on two, 1-mile-long, abandoned roads on the Desert Experimental Range. In this case, the wheatgrasses were drilled into the road; whereas, the natives were broadcast ahead of the drilling which was depended on to cover the broadcast seeds as well as plant the exotic wheatgrasses. The excellent early stands of the exotic wheatgrasses followed essentially the same pattern as shown in graph 1. But now after more than 25 years, components of most of the native plants can be found comprising a cover somewhat superior to the adjacent experimental range off the former roads. In fact, the once cleanly graded roads are only discernible by the somewhat better cover involving plants of some species which do not occur on the adjacent range. Prominent among these are fourwing saltbush, small rabbitbrush, winterfat, shadscale saltbush, Indian ricegrass, sand dropseed, and gooseberry globemallow.

There are other test plantings at the Desert Range Experiment Station in which fourwing, winterfat, sand dropseed, Indian ricegrass, needleandthread, blue grama, and Salina wildrye persist after 25 years in amounts to indicate future promise.

What of the future? I have alluded to it. I am convinced that a future program with concerted emphasis on discovering ecotypes of both native and exotic species should to some degree provide a suitable basis for artificial improvement of salt desert shrub ranges. The program is very much warranted. Actually, it is considerably past due. This will require a testing and selecting program of considerable magnitude. Such a program should be carried out in conjunction with a breeding

program aimed at improving the establishment attributes and the amplitude of adaptation of most promising species, but putting particular emphasis on shrubs. In the attached table are listed 68 species warranting careful scrutiny and approach. No doubt, there are others.

A great many observations in the past 15 to 20 years have shown that many closely related species have and are successfully hybridized in nature. Sometimes this has been an important avenue to speciation. It has been no less true in the salt desert shrub type than elsewhere. The development of new strains or species from the gradual flow of genetic materials across barriers from one population to another has been called introgression. The implications for the future, I believe, are evident.

Filled utricles and vigorous seedlings from the seed have been produced from recent artificial pollination by seven shrubby species in the saltbush complex on to the pistillate fourwing saltbush bushes. Three of these were different genera. Successful pollinators included shadscale saltbush, Gardner saltbush, mat saltbush, Nuttals saltbush, spiney hopsage, spineless hopsage, and black greasewood (Drobnick and Plummer 1966).

While this first artificial hybridization in this complex must be regarded as exploratory, the fact that it has been so easily carried out points to a tremendous potential for improving the quality of herbage from salt desert shrubs as well as for increasing their amplitude of adaptation. Here is a tremendous new field of inquiry where forthcoming results should be highly productive. Certainly, there is a bright future for improving depleted salt desert shrub ranges by artificial approaches

if we will take advantage of our past experience. Our need is for well trained, but more important, industrious and highly interested scientists in the field of ecology, genetics, cytology, and physiology, working together for the common objective. They must be willing to meet the challenge as a team. Their very best effort will be required. I am confident it can be done.

In conclusion, I paraphrase Solomon who said, "Go to the ant thou sluggard, consider his ways and be wise;" I would say, "Go to nature, range scientists, study her ways and improve her."

Species warranting thorough investigation of ecotypes for seeding various sites in the salt desert shrub type.

SHRUBS

Amelanchier utahensis	Utah serviceberry
Artemisia arbuscula	Low sagebrush
" frigida	Fringed sagebrush
" nova	Black sagebrush
" spinescens	Bud sagebrush
" tridentata	Big sagebrush
Atriplex canescens	Fourwing saltbush
" confertifolia	Shadscale saltbush
" corrugata	Mat saltbush
" gardneri	Gardner saltbush
" garrettii	Garrett saltbush
" nuttali	Nuttal saltbush
Cercocarpus intricatus	Littleleaf mountain mahogany
Chrysothamnus depressus	Dwarf rabbitbrush
" nauseosus	Rubber rabbitbrush
" parryi	Parry rabbitbrush
" viscidiflorus	Yellowbrush
Cowania mexicana stansburiana	Stansbury cliffrose
Ephedra nevadensis	Nevada ephedra
" viridis	Green ephedra
Eriogonum microthecum	Slenderbush eriogonum
Eurotia lanata	Winterfat
Fallugia paradoxa	Apacheplume
Fraxinus anomala	Singleleaf ash

Grayia spinosa	Spiney hopsage
" brandegei	Spineless hopsage
Poliomintha incana	Bushmint
Prunus andersoni	Anderson peachbrush
" fasciculata	Desert peachbrush
Purshia glandulosa	Desert bitterbrush
Salvia carnosa	Desert sage
Sarcobatus vermiculatus	Black greasewood
Symphoricarpos longiflorus	Longflower snowberry

GRASSES

Agropyron cristatum	Crested wheatgrass (Known in seed trade as Fairway crested wheatgrass)
" desertorum	Desert wheatgrass (Known in seed trade as standard crested wheatgrass)
" dasystachyum	Thickspike wheatgrass
" elongatum	Tall wheatgrass
" intermedium	Intermediate wheatgrass
" sibiricum	Siberian wheatgrass
" spicatum	Bearded bluebunch wheatgrass
" trichophorum	Pubescent wheatgrass
Bouteloua curtipendula	Sideouts grama
" gracilis	Blue grama
Bromus erectus	Meadow brome
Dactylis glomerata	Orchardgrass
Elymus ambiguum	Colorado wildrye

Elymus junceus	Russian wildrye
" salina	Salina wildrye
Hilaria jamesii	Galleta grass
" rigida	Big galleta grass
Hordeum bulbosum	Bulbous barley
Oryzopsis hymenoides	Indian ricegrass
Poa secunda	Sandberg bluegrass
Sitanion hystrix	Bottlebush squirreltail
Sporabolus airoides	Alkali sacatan
" contractus	Spike dropseed
" cryptandrus	Sand dropseed
Stipa arida	Mormon needlegrass
" comata	Needleandthread

FORBS

Artemisia dracunculoides	Falsetarragon sagebrush
" ludoviciana	Louisiana sagebrush
Aster canescens	
Astragalus	
Linum lewisii	Lewis flax
Penstemon palmeri	Palmers penstemon
Sphaeralcea grossulariaefolia	Gooseberryleaf globemallow
Viguiera multiflora nevadensis	Nevada showey goldeneye
Wyethia scabra	

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Techniques for Determining the Nutritional Value of Salt Desert Shrub Type for Cattle

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Range forage furnishes a large portion of the feed for our Nation's livestock. In spite of the importance of this feed source, research in this field has lagged far behind other nutrition research. Many of the techniques that have been used in other feed studies are simply not applicable to range research. Difficulties arise especially in the sampling of complex plant communities. This is particularly true when a comparison is made of the species actually consumed by cattle on the salt desert shrub type in relation to the species present.

Salt desert shrub has an historic background of very low productivity for range cattle. In Nevada there are 16.8 million acres of this type, yet it supports only 25,000 to 35,000 cows on a full time basis, or an average of 48 acres per AUM. Some areas within this vast domain are considerably more productive, having carring capacities, depending upon the year, of 10-20 acres per AUM. These more productive areas are of far more interest when considering the nutritional requirements of cattle.

Although the salt desert shrub is usually considered a winter use area for cattle, practically every type of grazing pattern can be found, ranging from year around use to very short seasonal use. Cattle grazing these areas are characterized by several abnormalities caused primarily by a low level of nutrition. Mature cows are usually small, often weighing as little as 650 pounds. Generally production is low, herds often have only a 50% or less calf crop. Bulls usually remain with the cows throughout the entire year. Weaning weights are low, usually averaging 250 to 300 pounds. In

addition, periodically high death rates occur. These are blamed on poisonous plants, disease, etc., but they are usually either a direct or indirect result of a low plane of nutrition.

The low livestock production on these areas is of obvious economic importance. Consequently, it has become important to know the nutrient value of the forage plants on these areas, and their contribution to the grazing animals' diet, so that any nutritional deficiencies can be corrected. A number of nutritional evaluation studies have been conducted on these ranges with cattle. A description of these studies and pertinent results follow.

Chemical Analyses of Key Species. The first attempts to nutritionally evaluate these ranges included chemical analyses of various key species of browse, forbs and grasses. Considerable data of this nature have been compiled, however, the most complete work for the salt shrub areas is that of Cook et al. (1954). A summary of several areas of work appears in table 1. Range nutritionists generally agree that the four most important nutrients to analyze forage for are protein, energy, phosphorus, and vitamin A (carotene). All can be readily determined except available energy. Crude fiber does give some indication of available energy, thus it is often included. Generally, the higher the fiber content, the lower forage digestibility and available energy. The protein content of salt desert browse remains fairly constant throughout the year at 10% or higher, which is adequate for most classes of livestock, providing intake is sufficient. Browse is fairly high in fiber, indicating the possibility of only borderline amounts of energy. Generally, they have more than adequate amounts of carotene. The browse plants appear slightly deficient in their phosphorus

content. Analyses of grasses associated with this range type have indicated far more seasonal variation. Protein ranges from 8-9% or higher in the spring, down to 4% or lower when material is mature and weathered. Grasses are more than adequate in phosphorus and carotene when green and growing, however, they become deficient in protein, phosphorus and carotene, and high in fiber after maturity. Analytical results such as these have given some idea as to the deficiencies of certain nutrients. Much of the early range supplementation work was based on results of this type. These data have also emphasized the variability of hand sampling in regard to time, location, species, etc.

Table 1. Composition of Typical Salt Desert Shrub Plants as Influenced by Season (Southern Utah and Nevada)

	% Protein	% Fiber	% P	Carotene mgs/lb.
White Sage (Eurotia lanata)				
Spring	13.1	32.7	0.11	5.7
Fall	10.3	34.5	0.13	8.2
Black Sage (Artemisia nova)				
Spring	9.8	34.7	0.14	5.1
Fall	8.2	41.5	0.15	12.8
Galleta Grass (Hilaria jamesii)				
Spring	8.5	25.5	0.14	-
Fall	5.5	38.0	0.06	0.1
Rice Grass (Oryzopsis hymenoides)				
Spring	9.2	24.6	0.15	-
Fall	3.7	49.2	0.05	0.0
Russian Thistle (Salsola kali)				
Fall	13.2	31.3	0.09	4.0

Development of Supplements. Techniques for supplementing range cattle on

salt shrub areas have been described by Bohman et al. (1955). These facilities involved the controlled use of water for bringing animals to the supplementation area. After entering the area, 8-10 animals may be fed their individual supplements at once. Sixty to 100 head of animals may be fed in this manner in a 2 to 3 hour period. Data from supplement programs on salt desert shrub type, for both cows and growing calves, are summarized in tables 2 and 3. (Speth et al., 1962; Bohman et al., 1961).

Table 2. Effect of Winter Supplements upon Cow Production on Salt Desert Shrub Type

	Control	1 lb. Barley per day	1 lb. CSM per day	3 lb. Alfalfa per day
Calving %	48	72	64	67
Weaning %	45	72	47	65
Weaning Wt. (pounds)	264	298	289	288
Prod. per cow (pounds/year	119	216	136	187

Table 3. Effect of Winter Supplements upon Calf Growth on Salt Desert Shrub Type

	Control	1 lb. Barley per day	1 lb. CSM per day	3 lb. Alfalfa per day
Initial Wt.	334	337	341	340
Final Wt. (346 days)	607	620	639	644
Avg. Daily Gain	0.79	0.82	0.86	0.88

	Phosphorus Supplementation	
	8 g Phos/Day (All Year)	0.87
Average Daily Gain	None	0.80

Energy and alfalfa supplements during winter periods increased weaning percent. Weaning weights of calves were heavier when barley was fed which resulted in considerably greater production for this treatment. Cows receiving protein supplements had significantly more calf deaths at birth than any other group. Phosphorus, fed year around had no effect upon reproduction. Feeding of similar supplements to growing calves during the winter period shows little advantage on a year around basis. Both phosphorus and winter protein supplements resulted in slight but increased gains. In addition to weight gains and reproduction performances certain biochemical measurements are often useful in evaluating range supplementation. These include vitamin A, carotene, phosphorus, protein and percent red blood cell measurements in blood. For the most part these measurements will add useful information to results obtained from range supplements. Plasma vitamin A levels in these range cows had always appeared adequate, however, recent trials using injectable vitamin A have shown some improvement in calving percent in cows grazing salt desert shrub areas in southern Nevada.

Often, on these ranges, both quantity and quality of water will be the limiting factor for range cattle. In studies in these areas cattle have been observed grazing up to 8 miles from water, however, usually they remained within 4 miles. It has also been observed that cattle come in for water only 55 days out of 100 (Bohman et al., 1961). Blaxter (1962) has developed tables for estimating energy requirements for movement of cattle. Using a theoretical example, it can be demonstrated that 75% of the net energy normally contained in forage of this nature that would be used for maintenance and production will be required for movement, if a cow walks 10 miles a day. If she is forced to do this daily because of scarcity of feed or available water, then in actuality she will have little or no net energy left over for production; this will result in loss of weight and

low reproducibility.

Contamination of water with salts is also of importance. If total salts surpass 7500 ppm, then quality becomes an important factor.

Estimating Composition of Ingested Forage. Numerous techniques have been attempted to estimate composition of animal intake. Cook et al. (1948) developed the "before and after" method of plant sampling to measure the nutrient content of the diet of animals grazing these areas. Development of esophageal fistulated cattle (Torell, 1954) and rumen fistulated cattle (Lesperance, 1960) have greatly facilitated sampling of complex ranges by grazing cattle. Data have been published (Connor et al., 1963) concerning animal preference on salt shrub ranges in southern Nevada. Samples obtained from rumen fistulated animals may be analyzed both botanically and chemically. Data from these studies are summarized in tables 4 and 5.

Table 4. Botanical Composition of Forage Selected by Rumen Fistulated Steers on a Salt Shrub Area.

Year	Month	% Grass	% Browse	% Forbs
1959	July	34.7	64.3	1.0
	Aug.	14.0	85.4	0.6
	Sept.	9.2	90.7	0.1
	Oct.	2.3	97.7	-
	Nov.	7.2	92.8	-
	Dec.	4.7	95.3	-
1960	Jan.	26.1	73.9	-
	Feb.	17.9	82.1	-
	March	21.8	78.2	-
	April	38.8	61.2	-
	May	80.9	19.0	-
	July	85.0	15.0	-
	Aug.	39.8	60.1	-
	Sept.	0.2	99.8	-
	Oct.	0.0	99.0	1.0

Table 5. Chemical Composition of Forage Selected by Rumen Fistulated Steers on a Salt Shrub Area.

Year	Month	% Protein	% Fiber
1959	July	10.7	32.4
	Aug.	12.8	36.5
	Sept.	12.9	38.6
	Oct.	9.1	35.4
	Nov.	9.6	36.5
	Dec.	9.6	39.4
1960	Jan.	9.1	43.0
	Feb.	6.4	36.6
	March	7.5	39.9
	April	12.0	32.7
	May	12.9	31.5
	July	10.1	29.2
	Aug.	9.1	30.8
	Sept.	10.4	30.4
	Oct.	10.2	32.5

Botanical composition of these samples varied greatly with season. Grass consumption was low in fall and winter, and increased in spring and summer. Low consumption of grass did not indicate a preference for browse in winter periods, as virtually all grass had been grazed. During spring and summer months grass made up less than 10% of the plant cover, yet fistula samples contained as much as 85% grass in July. Hilaria jamesii was the predominant grass species in this study, however, other grass species, especially Oryzopsis hymenoides, are equally important. Cattle show relatively little preference for any one species of grass, usually consuming all species in about the same proportion as they are present on these ranges. Eurotia lanata was the primary browse species except during the winter months when Ephedra nevadensis appeared more. Other shrubs of some importance are Atriplex species and Artemisia spinescens. In these studies forbs were not consumed. More recent observations indicate Salsola kali and Sphaeralcea ambiguia are consumed quite readily during certain periods. Protein content

of fistula samples appears adequate for all classes of livestock except growing animals during winter periods. Fiber increased as plants matured suggesting a drop in available energy.

Intake and Digestibility Studies. Attempts have also been made to determine both intake and digestibility of these forages. Many techniques are currently being developed to help facilitate studies of this nature. Data from salt desert shrub range are presented in table 6. (Connor et al., 1963). Consumption of dry matter appears low. The requirements of

Table 6. Consumption and Digestibility of Certain Nutrients by 400 Pound Yearling Calves Grazing on a Salt Shrub Area.

	Actual	Required*	% Deficient
Pounds of Dry Matter Per Day	7.1	10.5	32%
Pounds of Digestible Protein Per Day	0.5	0.7	28%
Pounds of Total Digestible Nutrients Per Day	3.3	5.3	38%
Therms of Digestible Energy Per Day	7.0	10.5	33%
Therms of Metabolizable Energy Per Day	5.5	-	-

*NRS requirements for 400 pound animal to gain one pound per day.

digestible protein and digestible energy for moderate growth were not met during any of the periods studies (summer). From this study it would appear that the concentration of nutrients in the forage was adequate for some production, but that the limiting factor was simply the availability of forage. This leads directly to a deficiency of net energy. Furthermore, if energy requirements are greatly increased by movement, then it becomes

obvious that production cannot be expected to be high under even the best economical supplementation program on the salt desert shrub type.

Continued research into the nutritive value of the salt desert shrub type for cattle will certainly produce more information regarding its proper utilization. With the techniques that have been developed, more meaningful results can be readily obtained in the future concerning the quality and quantity of the grazing animals' diet. Production will always be low on these areas when compared to other range types, however, proper management coupled with a sound range supplementation program, based on research results, will undoubtedly increase cattle production on the salt desert shrub type.

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NUTRITIONAL VALUE OF THE SALT-DESERT SHRUB RANGES

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Deficiencies most common on salt-desert range types are protein, energy, phosphorus, and carotene (vitamin A). Such deficiencies are more apt to occur when ranges are overgrazed, during periods of drought or when ranges are in a deteriorated state. These deficiencies may appear singly or in any combination.

Nutritional requirements of livestock vary accordingly to age and stage of development of the animal and phase of production such as maintenance, gestation, growth, fattening and lactation.

Range forage is selected by the grazing animal in varying quantities and in an assortment of species and portions of plants. For this reason it appears impractical to establish recommended standards for nutrient requirements in terms of pounds or grams as is commonly done under farmlot conditions. For these reasons range standards are presented in terms of percent or quantity of nutrient per pound of forage to meet the requirements under proper grazing management.

Salt-desert shrub ranges are generally used during the winter when the animals are in gestation or are merely maintaining their weight. Therefore, the forage should contain about 4.4 percent digestible protein, 665 calories of metabolizable energy per pound, 0.5 mg. of carotene per pound, and 0.17 percent phosphorus.

Vitamin A is stored in the body and requires from 90 to as long as 200 days for its depletion in livestock. Thus animals coming from summer ranges where carotene content is high could subsist on substandards of carotene for 5 or 6 months without harm. Browse plants of the salt-desert ranges are excellent sources of carotene and when the diet consists of as much as 15 percent of these plants, there is no reason to suspect a Vitamin A deficiency.

In general, browse species of the salt-desert shrub types meet the range standards for protein for livestock during gestation. However, they may be slightly deficient in phosphorus and decidedly low in energy-furnishing constituents.

Grasses associated with the browse species of the salt-desert shrub types are markedly deficient in protein, phosphorus and carotene but are good sources of energy (Table 1).

Table 1 Average Nutrient Content of Grass and Browse Species of the Salt-desert Shrub Types Compared to good Sun Cured Alfalfa

	Digestible Protein %	Metabolizable Energy Cal/lb	Phosphorus %	Carotene mg/lb
Grass	0.2	800	.07	0.23
Browse	4.7	614	.12	7.20
Alfalfa	10.5	899	.21	7.90

Forbs are generally sparse on salt-desert shrub types and are unimportant in the diet during winter grazing.

A mixture of grass and browse in the diet would more nearly balance the ration than either forage class alone but it may not fully satisfy any of the nutritional requirements. This depends upon the quantity of each forage class in the diet and the species of plants involved. Individual species within a forage class will vary considerably and may be higher or lower than the average for the forage class it represents. Shadscale is relatively low in protein and phosphorus and black sage is relatively high in both during the winter grazing season.

A variety of vegetation conservatively grazed reduces the need for supplements on salt-desert ranges. Overgrazing may result in a need for a greater quantity or even a more expensive supplement over a longer period of time.

PLANT ECOLOGICAL RESEARCH IN UTAH'S SALT DESERT AREAS

NEIL E. WEST[1/]

Other papers herein emphasize the importance of salt desert shrub ranges in general, and in other states. In Utah this range type is particularly prominent, amounting to approximately 19,000 square miles or about 12 million acres. This adds up to about 22% of the land area of the state. Only Nevada has more land occupied by salt desert shrub vegetation.

Utah has three basic areas of salt desert shrub occurrence: First is the "West Desert" that occurs to the west or Great Basin side of the Wasatch Mountains. This area includes such valleys as Curlew, Rush, Pine, Wah Wah and the Escalante Desert. The second largest area is locally called the "East Desert." This label includes the Grand River Valley, the Green River and Sindbad Deserts, and other smaller areas. The third principal salt desert shrub area is in the Uinta Basin.

This large Utah winter range type has attracted the interest of a long succession of ecologists. Most of the interest has been shown in the "West Desert." Such distinguished names in ecology as H. L. Shantz, F. E. Clements and J. A. Harris were early interested in plant indicator significance of salt desert shrub species for salinity-alkalinity. This early work was primarily related to predicting success for agricultural conversion.

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Soil-vegetation relationships have continued to attract interest up to the present time. Studies of changes in salt desert shrub vegetation patterns due to grazing and other causes have been frequent. However, in the past, research on other aspects of salt desert ecology has been meager.

All of this prior work is a matter of record (West 1966). I feel it most appropriate for this symposium to narrow the scope of my review to the work that the Range Science Department at Utah State University has done and is doing on the ecology of the salt desert shrub type.

We have long been interested in this vegetation. L. A. Stoddart has maintained an interest in this type for over 30 years. C. W. Cook has been working in the type for 20 years. Thus, necessarily much of the past work reviewed in the following is that of the author's colleagues and students.

The invasion of halogeton, if not for the stockman, has been rather a fortuitous happenstance for both researcher and manager. First of all, it attracted attention to the importance of salt desert ranges, providing research funds, producing research results that have in turn allowed management guidelines to become established. As with many of the other programs reported on at this symposium, our studies got underway with the impetus created by halogeton invasion.

Our first full scale ecological study was completed by Dillard Gates in 1956. He studied the inter-relationship of vegetation and primarily soil chemical characteristics in pure stands and across alternes for shadscale, Nuttall's saltsage, winterfat and greasewood in Curlew Valley, Rush Valley and the Escalante Desert in Utah and

also the Raft River Valley of Idaho. Differences between soils occupied by the species were significant for only 5 of the 20 edaphic factors studied, these were: total soluble salt, saturation extract conductivity, exchangeable sodium, soluble sodium and 1/3 atmosphere moisture percentage. Although the means of these variables differed significantly, there was a common range for all species for all factors studied. This work greatly depreciated the indicator concepts built up by earlier workers. The presence of pure communities and sharp alternes were not explained away by sharp or consistent changes in soil chemistry (Gates et al. 1956).

Using the logic that Lake Bonneville may have had various types of lacustrine deposits, the physical characteristics of which may influence present vegetation distribution, Mitchell et al. (1966) looked at soil physical characteristics for soils under some of the same communities studied by Gates in Curlew Valley. No significant differences in texture, structure, bulk density, gross or micro-mineralogy were noted for soils under pure communities and across ecotones between shadscale, winterfat and Nuttall's saltsage.

While soil-vegetation studies in the West Desert seemed confusing, studies by Ibrahim (1963) and Singh (1967) in the Grand River Valley near Cisco, Utah pointed out very close and consistent relationships between geology, soils, and vegetation. Four plant communities have been statistically defined for a 13.5 square mile study area. These are the (1) shadscale (Atriplex confertifolia)-galleta grass (Hilaria jamesii) community, (2) saltbush (A. nuttallii var. nuttallii)-galleta

grass community, (3) saltsage (A. nuttallii var. gardneri)-woody aster, and (4) the mat saltbush (A. corrugata) community.

Support from edaphic and geologic evidence shows that the study area has been subjected to several pronounced cycles of soil erosion. The directional changes between the four communities are influenced by the retrogressional processes to which the pediment remnants and the Mancos shale bedrock are subjected. The pediment remnants are vegetated by the shadscale-galleta grass community. On eroded sites of the pediment remnants this community is replaced by the saltbush-galleta grass community. The saltsage-woody aster community occupies areas where the pediment remnants are eroded away and the Mancos marine shale is exposed to the ground surface. The mat saltbush community dominates the alluvial deposits originating from the three previous habitats.

The value of the four communities as indicators of soil conditions in the shadscale zone of southeastern Utah is quite clear cut. The shadscale galleta grass community was found to occupy coarse-textured soil suggesting that this community is adapted to soils of low water holding capacity. Soils under this community were non-alkali throughout the soil profile. They were non-saline in the surface 2.5 feet but saline at greater depths. This community is indicative that a distinct lime zone 9 to 16 inches in thickness occurs from 15 to 29 inches below the soil surface.

Soils under the saltbush-galleta grass community are loamy and non-alkali throughout the soil profile. They are non-saline in the surface 15 inches but saline at greater depths. This community is a

reliable indicator that a gypsiferous horizon 7 to 17 inches in thickness occurs from 2 to 4 inches below the soil surface.

The saltsage-woody aster community occurred on fine-textured soils that were non-alkali throughout the soil profile. The soils were non-saline in the first foot but saline at greater depths.

The mat saltbush community grows on heavy-textured soils that are saline-alkali throughout the profile. The salinity and the amounts of exchangeable sodium in the surface 5 inches varies slightly. However, this variability does not limit the use of this community as an indicator of saline-alkali soils.

A reconnaissance of approximately 200 square miles around the area was undertaken to investigate the occurrence of the four communities and their associated soils. This reconnaissance revealed that four ecosystems can be recognized on the basis of vegetation, soil, and geologic information obtained from the intensive survey of the study area. Therefore, the results obtained from the study area might be extrapolated to a larger portion of the perennial Atriplex-dominated vegetation throughout the Colorado Plateau Province in southeastern Utah and adjacent Colorado.

The aforegoing work has been extensively used to stratify the more current ecological work plus the watershed studies described by Coltharp and West (1966).

Studies of vegetation changes in Curlew and Rush Valleys in Utah and near Arco, Idaho during the last ten years have been conducted by making periodic readings inside and outside of exclosures, in pure

communities and across alternes. The most important result is the loss of density and areal extent of winterfat and perennial grasses in heavily grazed situations. Exclusion of livestock, rodent, and lagomorph utilization has allowed pronounced increases in winterfat and perennial grass densities. Winterfat when heavily grazed loses ground to shadscale and big sagebrush. Halogeton and Malcomia africana are found at about 30 times greater densities on heavily grazed sites compared to adjacent exclosures. All ecotones have remained fairly stable except those in which winterfat is a combination. This species is losing ground at all sides. Studies of artificial reduction of competition shows this change not to be due to a lack of competitive ability of winterfat but simply due to the fact that it is so highly preferred compared to competing species that vigor is reduced to an excessive extent. A status quo seems to have existed during the last 8 - 10 years at alternes where winterfat is not involved. However, densities of desirable forage species such as black sagebrush, budsage, Nuttall's saltbush, Indian rice grass, Sandberg's bluegrass and squirreltail have all increased in density with grazing exclusion.

An interesting finding by Baascher (1961) was that winterfat and saltsage tend to have a more random dispersion pattern under heavy grazing whereas the pattern becomes more regular as range condition improves. There is a possibility that these characteristics could be used in range condition and trend analysis. As with other species, a plot size of 2 1/2 to 2 2/3 times mean area is most adequate for sampling these species.

In addition to the aforegoing synecological studies, we have concomitantly carried out autecological investigations of the more prominent salt desert shrub forage species.

These studies have included: seed germination, seedling establishment, phenology, and seed production. Species studies include Atriplex confertifolia (Hussain 1966), Atriplex nuttallii, Atriplex corrugata, Artemisia nova, Eurotia lanata, Sphaeralcea grassularceafolia (Page et al. 1966), Elymus salina, and Hilaria jamesii. For the latter species, New Mexico, Arizona, Nevada and Wyoming Agricultural Experiment Station range scientists are becoming involved in the regional research project, W-90, on the autecological life history of galleta grass.

Some things of general interest from our autecological studies to date: We've found very little in the way of thermoperiodic or photoperiodic control existing for growth, flowering or seed production for salt desert species. These plants flower and reflower in a broad amplitude of temperature conditions as long as soil moisture is adequate. The soft seeded species, particularly winterfat, have little in the way of pre-treatment requirements for seed germination whereas the other harder seeded species have germination requirements which enable that particular crop of seeds to make reproduction more effective over a number of years. This could well be part of the explanation of the success of shadscale and scarlet globemallow on more disturbed sites.

Because no year has a typical pattern, many more years of concomitant collection of phenological and climatological data will be necessary before a more complete picture of plant and climatic environment relationships may be drawn.

One of our more promising current efforts deals with studies of ecotypic variation. Workman (1967) has been studying the effects of temperature and salinity on germination of winterfat. We got into this study after a re-analysis of Gates' earlier data on soil salinity-vegetation relationships. We found significant valley to valley variation in the soil salt concentrations in which winterfat was found growing. This made us suspect ecotypic variation might be operating to confuse the issue and depreciate the indicator value of this and other salt desert shrub species. By germinating seeds from various sources against various levels of NaCl in agar on petri dishes, highly significant source variation showed up. That edaphic ecotypes exist was also substantiated by reciprocal transplants of each source on its own soil. We are actively pursuing this line of research and have plans for studying within valley variation as well as ecotypic variation in the other chenopod species. This area of effort holds considerable hope for helping us explain the discrepancies in indicator values. Of course, the repercussions to reseeding attempts could be considerable.

Other future work we hope to get into will be in the realm of ecophysiology. That is, we intend to study photosynthetic, respiratory and water consumptive rates of these important species under various

field and controlled conditions. Relation of physiological processes to environmental conditions should allow us to better define the bottlenecks involved in plant growth on salt deserts.

Soil moisture and salinity dilution patterns will be followed in detail now that instrumentation is available to more adequately study these phenomena. These studies will be coupled with micro-meteorological studies in various salt desert ecosystems.

Many interesting plant ecological studies remain to be done in salt deserts. This is a most fascinating range type, challenging the ecologist to answer unique questions.

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THE BADGER WASH STUDY

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Introduction

The study I am going to discuss is generally referred to as the Badger Wash Interagency Cooperative Study.

In the early 1950's, the Sedimentation Sub-committee of the Pacific Southwest Interagency Technical Committee recognized the need for quantitative data on the effect of treatment practices on sparsely vegetated Salt-Desert-Shrub occupied lands underlain by highly erodible rocks and soils. An example of this type is the thousands of square miles occupied by the Colorado Plateau in western Colorado. In 1953 the Sub-committee selected the Badger Wash Basin for the study of erosion and sedimentation problems of the type because it was considered typical of a large part of the Colorado Plateau.

Objectives

The primary objective of the study was to compare runoff and sediment yield from grazed and non-grazed watersheds. Other objectives were to determine: (1) the amount and rate of runoff and sediment yield from storms of varying magnitudes and durations, (2) the relative infiltration and erosion rates on different soils and their response to grazing treatment, (3) the effect of livestock

exclusion on vegetation and other watershed cover, and (4) the relative abundance of small rodents and rabbits on grazed and non-grazed areas.

Cooperating Agencies

Under the terms of a cooperative agreement four Federal agencies began cooperation in the study in 1953; these agencies are the Bureau of Land Management who provided the land and constructed and maintained physical structures, e.g. retention dams, fences, and roads, the Bureau of Reclamation who assisted the BLM financially and conducted topographic surveys, the Geological Survey who maintained climatic records and measured runoff and sediment yields, and the Forest Service who conducted infiltration and vegetation studies. In 1955 the Fish and Wildlife Service entered into the study for the purpose of following small mammal and rabbit populations.

A co-ordinating committee made up of a representative of each of the agencies met annually to discuss accomplishments and plan future work.

Description of the Study Area

The Badger Wash study drainage occupies an area of about 7 square miles in the Salt-Desert-Shrub type about 8 miles northwest of Mack, Colorado (about 25 miles west of Grand Junction).

Before the Taylor Grazing Act was established in 1934, grazing use was unrestricted and heavy; since the construction of the retention dams necessary for the study, livestock use has remained heavy

because these dams provide an abundance of watering places within a relatively small area.

The elevation at Badger Wash averages about 5,000 feet; mean annual precipitation is a little less than 10 inches, over half of which occurs as high-intensity, short-duration storms during the summer; temperatures vary from below 0 to 100 degrees F.

Three types of soils are found in the area: (1) heavy clays derived from Mancos shale, (2) sands derived from sandstone lenses in the Mancos shale, and (3) mixtures of the two: the mixed type predominates.

Sheet and gully erosion is moderate to severe throughout the area.

The most abundant shrubs of the area are Greenes and rubber rabbitbrush (Chrysothamnus greenei and C. nauseosus), shadscale and Gardner saltbush (Atriplex confertifolia and A. nuttallii), snakeweed (Gutierrezia sarothrae), and Tetradymia (Tetradymia spinosa). Shrubs of lesser importance are big sagebrush (Artemisia tridentata), mormon tea (Ephedra sp.), mat saltbush (A. corrugata), and prickly pear (Opuntia engelmannii). These shrubs are found primarily on the poorer soils.

The most abundant grass in the area is galleta (Hilaria jamesii) which, along with winterfat (Eurotia lanata), is found in fairly good stands in relatively small areas on the better soils. Occasional plants of Salinas wildrye (Elymus salinas), Indian ricegrass

(Oryzopsis hymenoides), sand dropseed (Sporobolus cryptandrus), sandburg bluegrass (Poa secunda), and squirrel tail (Sitanion hystrix) are scattered throughout the area.

A wide variety of forbs are present in the area, the principal ones being species of Aster, Astragulus, Eriogonum, Lappula, and Phlox.

The Badger Wash study area is approximately 4 1/4 miles long (north-south axis), 2 miles wide, and consists of numerous small drainages which drain into the main channel along the long axis of the basin.

At the outset of the study two pairs of watersheds were selected on each side of the main drainage. The members of each pair were selected so that the two were as nearly alike as possible with respect to size, topography, soils, and vegetation; this procedure was adopted in order to eliminate the need for a calibration period. One watershed of each pair was fenced to exclude grazing; the other member received normal grazing use.

The soils of the western two watershed pairs are predominately sands and the vegetation is predominantly shrubs, but there are small areas that are dominated by galleta and winterfat. The slopes of these watersheds are relatively gentle except for the upper reaches where the drainages head.

The soils of one of the eastern watershed pairs are mostly clay and mixed, and the soil of the other is all mixed. The vegetation of both of these eastern pairs is almost exclusively shrubs, and the slopes are very steep.

Both cattle and sheep grazed the area yearly during the period November 16 to May 15. In 1966 the grazing allotment changed hands and use was (and will continue to be) by sheep only for a 30-day period sometime between December 1 and March 1.

At the advent of the study the area was characterized by 59 percent bare soil and 18 percent rock (a bare soil and rock total of 77 percent); the remaining 23 percent consisted of 17 percent litter, 4 percent perennial plants, and 2 percent moss. Shrub crown were recorded on 13 percent of the observation points and considering hits on both understory and overstory, 28 percent of the ground surface had a protective cover of litter, moss, and living plants.

The west half of the watershed (characterized by better soils and gentler slopes) had significantly more cover (8 percent) at the start of the study. There were no significant differences in plant cover between the members of the watershed pairs at the outset of the study, but the non-grazed ones had 5 percent more bare soil.

Findings

Small Mammal and Rabbit Populations 1/

Live trapping on a grid, and snap trapping on transect lines were used to sample small mammal populations annually in May; total trap night was 1400 annually. Logomorph abundance was followed by making counts and removing pellets semi-annually from permanent plots and by making counts of animals flushed in walking strips on the watersheds.

1/ This phase of the study was designed and the data collected by V. H. Reid, Biologist, U.S. Fish and Wildlife Service, Fort Collins, Colorado.

Population levels of small mammals and rabbits were quite low during the nine years that population levels were determined.

The most abundant small mammal in the area is the deer mouse (Peromyscus maniculatus). The deer mouse population did not exceed 3.7 animals per acre (averaged over all watersheds) during the nine years of sampling, and there was no major or consistent difference in population of deer mice on grazed and non-grazed watersheds. Limited numbers of harvest mice (Reithrodontomys megalotis) were inventoried in the area during the course of the study, and the number of this species increased in 1964 and 1965, but the population level of the species was less than one animal per acre.

In addition to deer and harvest mice, pinon mice (Peromyscus truei), kangaroo rats (Dipodomys ordii), and white-tailed antelope squirrels (Citellus leucurus) were inventoried, but catch of these animals has been only occasional, and their populations are considered very small (less than one animal per acre).

Indices of populations show that black-tailed jack rabbits (Lepus californicus) and desert cottontails (Sylvilagus audubonii) have been more abundant on non-grazed than on grazed watersheds, but these species were never abundant.

Small mammal and rabbits did not appear to contribute appreciably to the results of the study.

Infiltrometer Study 2/

Infiltrometer runs were made at 12 randomly selected locations in each watershed in September 1954, 1958, and 1963. The results of this study are inconclusive, as the 1963 infiltration rates are lower than the pre-treatment rates for both grazed and non-grazed plots. Statistical analysis of the infiltrometer-plot data has not been accomplished as yet, but it is doubtful that there will be any significant differences which can be attributed to treatment effects.

Utilization Estimates 3/

Utilization estimates were made on the grazed watersheds each spring at the close of the grazing season. The purpose of these estimates was to determine the degree of treatment, i.e., degree of grazing use. The ocular estimate-by-plot method was used in making these estimates. Estimates were made on 24 two-by-fifty foot plots in each watershed. Use of old grass growth ranged from 60 to 90 percent for the more palatable grasses, e.g. Salinas wildrye, Indian ricegrass, and sandburg bluegrass growth was also heavy, ranging above 50 percent during most years. Use of new growth of shrubs and grasses and use of forbs was dependent upon the amount of spring growth; during years when there was a good spring moisture and growth was good, use was

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2/ This phase of the study was designed, and the data collected by J. R. Thompson, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

heavy. During some years, there was no forb growth prior to May and, of course, there was no use.

Vegetation Cover Measurements 4/

A modification of the Parker 3-step method was used for determining vegetative cover. Twelve transect clusters consisting of two 50-foot permanent transects were established in each watershed. The transect clusters were located at random within major soil types with the number of clusters in each type being in proportion to the area occupied by the soil type. Observations were made at 6-inch intervals along a 50-foot steel tape stretched between two steel stakes located at each end of the transects. The data was recorded as shown in Figure 1. The definitions of the factors recorded were as follows:

Bare soil. Soil that occupies more than half the loop and is not covered with rock or organic matter.

Rock. Rock particles at least one-eighth inch in diameter that singly or together occupy more than half the loop.

Litter. Dead organic matter that occupies more than half the loop, except leaves still attached to live plants.

3/, 4/ This phase of the study was designed and the data collected from 1953 through 1964 by G. T. Turner, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Plant density index. The number of hits on root crowns of perennial plants in 100 observations.

Shrub overstory. Any portion of a shrub crown, except openings within the crown, that occupies any portion of the loop.

Ground cover index. An expression of watershed cover computed as 100 minus the number of hits on bare soil and rock not under a shrub overstory.

Cover Changes

It should be noted that changes that occurred were not of a large magnitude; they generally ranged from one to six percent. In the following discussion all changes mentioned will be statistically significant ones with the exception of the comparisons of the 1966 data with the data of previous years. I feel sure that the changes I will mention in comparing the 1966 measurements with earlier measurements are significant, but statistical comparisons have not been made.

There are three ways that the changes or lack of changes in the vegetation of the area from 1953 through 1966 can be discussed.

The first is based on measurements made in 1953 and 1955. The results of these measurements are presented in Figure 2. These results may not be particularly meaningful because the 1953 measurement was made in the fall, and the 1955 measurement was made in the spring. At any rate, there were some significant increases in protective cover on non-grazed watersheds and decreases on all grazed ones. The amount of bare soil and rock increased on all watersheds (Figure 2), but the amount

of increase was consistently less on the non-grazed watersheds; likewise, the amount of litter and moss decreased on all watersheds, and the decrease was greater on the grazed watersheds than on non-grazed watersheds. At this time it appeared that the protected watersheds were improving and that the grazed watersheds were deteriorating.

A second way that the vegetation changes can be compared is based on fall measurements in 1953 and 1963. The results of these measurements indicate that the vegetative cover of the non-grazed watersheds did not change appreciably during this 10-year period, whereas the grazed watersheds deteriorated (Figure 3).

A third way that the vegetative changes can be compared is based on spring measurements made in 1955, 1958, 1963, and 1966. The changes in vegetative cover on the watersheds, which occurred from 1955-58, 1955-63, and 1955-66, are presented in Figure 4, and the changes which occurred from 1955-58, 1958-63, and 1963-66 are presented in Figure 5.

During the period from 1955-58 and 1955-63, the non-grazed watersheds seemed to be responding to treatment as bare soil and rock decreased and litter and moss and ground-cover index increased on all watersheds (Figure 4). However, during the period 1955-66, plant density index decreased on more non-grazed watersheds than on grazed watersheds; during the same period shrub overstory decreased on all watersheds, and ground-cover index decreased on 3 non-grazed and on all grazed watersheds (the average decrease on grazed watersheds being more than four times greater than on non-grazed watersheds.)

Bare soil and rock decreased, and litter and moss increased on all non-grazed watersheds during all periods; this trend was generally reversed on grazed watersheds.

The increase in bare soil and rock on non-grazed watersheds from 1963-66 (Figure 5) may be due to the prevalence of drought conditions during the 1965-66 winter and 1966 spring; this was the driest winter-spring in the area since 1909. Also, many perennial species, which were present in the area at the start of the study (1953) were not encountered in 1966, e.g. Poa secunda, Sporobolus cryptandrus, Abronia fragrans, Aster hirtifolius, 4 species of Astragulus, Bahia nudicaulis, and Stanleya pinnata; also one species each of Allium, Calochortus, Crypthantha, and Cymopterus disappeared from the sampling location sometime between 1963 and 1966.

Precipitation, Runoff, Sediment, and Erosion Measurements 5/

At the outset of the study, rain gages were installed in the area so that two gages served each adjacent watershed pair; one gage was placed near the upper end of each pair, and one was placed near the lower end near the retention dams, where continuous water-stage recorders were installed for volumetric measurement of runoff. Sediment volume was measured yearly or more frequently in the reservoir of each watershed.

5/ This phase of the study was designed and the data collected by G. C. Lusby, Research Hydrologist, U. S. Geological Survey, Denver, Colorado.

A representative sample of the runoff and sediment yields measured during the course of the study are presented in Figure 6.

Runoff and sediment yield from the non-grazed watersheds was consistently less than from the grazed watersheds, and the differences in runoff were obvious as early as 1954 (the first year after initiation of the study). No sediment yield measurements were made in 1954.

Erosion trend studies indicate that the reduction in runoff and sediment as a result of protection are largely influenced by the characteristics of the Mancos shale derived soils. Observation of erosion stakes (steel stakes driven flush with the soil surface) show that "during winter the soil surface is loosened by frost action, and the stakes show minimum exposure in the spring. Rain-beat during the spring and summer compacts the soil, and the stakes show maximum exposure during the fall. Frost action and compaction cause creep to occur in the upper 2 inches of the lithosols. During spring and summer, compaction of the soil by rain-beat decreases infiltration capacity, and runoff increases. Rills form on the slopes, but these are soon destroyed by winter frost action and creep, and the infiltration capacity of the soil is increased. 6/ Precipitation and runoff data reflect these seasonal changes in soil characteristics as runoff, and the runoff-precipitation ration is less in the spring than in the fall.

6/ Schumm, S. A. and G. C. Lusby. 1963. Seasonal variation of infiltration capacity and runoff on hill slopes in western Colorado. J. Geoph. Res. 68(12): 3655-3666.

Lusby [7] concludes that "in grazed basins trampling by livestock causes an earlier and more pronounced compaction of the loosened soil, but in ungrazed basins the soil remains loose for a longer period of time and greater infiltration occurs. Therefore, the grazed basins yield higher rates of runoff and sediment yield, despite negligible changes in vegetation cover, because of the longer period of compaction resulting from livestock trampling."

Summary and Conclusions

Protection from grazing in the Badger Wash area has resulted in a decrease in runoff and sediment yield. The reasons for this decrease are not readily apparent. The vegetational changes measured do not seem great enough to be responsible for the change; in fact, vegetational cover declined on all watersheds during the last three years of study and the decline was greater on the non-grazed than on the grazed watersheds.

Little specific information is available on the soil characteristics of the type, but it seems likely that soil peculiarities and livestock trampling may be largely responsible for the differences observed.

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[7] Lusby, G. C. 1965. Causes of variation in runoff and sediment yield from small drainage basins in western Colorado. USDA Misc. Pub. No. 970, Paper No. 14, pp. 94-98.

Figure 1. RECORD OF PERMANENT LINE TRANSECT

Study Area: Badger Wash Observer:_____ Date:_____

1	2	3	4	5	6	7	8	9	10
									Aco
-	-	-	R	-	-	-	-	Aco	L
11	12	13	14	15	16	17	18	19	20
							Aco	Aco	Aco
-	-	H	H	L	L	Hja	-	L	L
21	22	23	24	25	26	27	28	29	30
-	-	R	R	L	L	Ory	-	-	-
31	32	33	34	35	36	37	38	39	40
					Atr	Atr	Atr		
-	-	-	-	-	Atr	L	-	R	-
41	42	43	44	45	46	47	48	49	50
-	-	-	-	-	-	Esa	-	R	L
51	52	53	54	55	56	57	58	59	60
Tsp	Tsp	Tsp							
L	R	-	-	-	-	-	-	R	L
61	62	63	64	65	66	67	68	69	70
		Acg	Acg						
-	-	-	L	-	-	-	-	-	a
71	72	73	74	75	76	77	78	79	80
-	-	-	a	-	R	M	M	M	-
81	82	83	84	85	86	87	88	89	90
-	-	-	-	-	M	M	-	L	-
91	92	93	94	95	96	97	98	99	100
				Anu		Anu			
-	-	L	L	L	Anu	L	-	-	R

Watershed No._____

Cluster_____ Transect_____

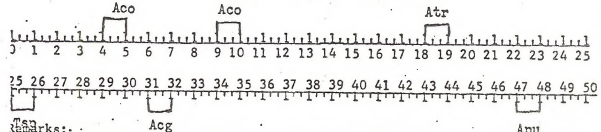
Soil: Mixed____:Shale____:Sand____

TRANSECT SUMMARY

	Sym.	Hits
Bare soil.....	-	61
Rock.....	R	11
Litter.....	L	17
Moss (or lichen)...	M	5
Plant density index		6
Total		100
Overstory shrubs		14
Ground cover index		34
Annuals		2

Sym.:	Species	:Base:	Over
Atr	:Artemisia tri.	: 1	: 3
Ahi	:Aster hirtifol.	:	:
Ave	:Aster venustus	:	:
Aas	:Astragalus ascl.	:	:
Acn	:Astragalus conf.	:	:
Ami	:Astragalus miss.	:	:
Aco	:Atriplex confer.	: 1	: 1
Acg	:Atriplex corrug.	:	: 2
Anu	:Atriplex nuttal.	: 1	: 2
Bnu	:Bahia nudicaul.	:	:
Cgr	:Chrysotham. gr.	:	:
Cel	:Cryptantha elat.	:	:
Esa	:Elymus salinus	: 1	:
Epu	:Erigeron pumil.	:	:
Ebi	:Eriogonum bicol.	:	:
Eov	:Eriogonum oval.	:	:
Gsa	:Gutierrezia sar.	:	:
Hja	:Hilaria jamesii	: 1	:
Ohy	:Oryzopsis hymen.	: 1	:
Plo	:Phlox longifol.	:	:
Shy	:Sitanion hyst.	:	:
Sco	:Sphaeralcea coc.	:	:
Tsp	:Tetradymia spin.	:	: 3
	Totals	: 6	: 14
		:	:

Intercept of Shrub Crowns



Spp.:	Ft.
Aco :	2
Atr :	1
Tsp :	1
Acg :	1
Anu :	1
	6

Remarks:

Figure 2.-- Comparison of changes in cover at Badger Wash from the fall of 1953 to the spring of 1955 on four grazed and non-grazed watersheds.

Factor	Grazed	Non-grazed
Bare soil and rock	4 Inc. 1/	4 Inc.
Litter and moss	4 Dec.	4 Dec.
Plant-density index	4 Dec.	4 Dec.
Shrub overstory	4 Dec.	3 Inc. 1 Dec.
Ground-cover index	4 Dec.	2 Inc., 1 NC, 1 Dec.

1/ Inc. = Increase
Dec. = Decrease
NC = No change

Figure 3.--Comparison of changes in cover from 1953-63 on four grazed and non-grazed watersheds at Badger Wash (fall measurements).

Factor	Grazed 1953-63	Non-grazed 1953-63
Bare soil and rock	4 Inc. 1/	4 NC
Litter and moss	3 Dec., 1 NC	4 NC
Plant-density index	2 Dec., 2 NC	1 Dec., 3 NC
Shrub overstory	3 Dec., 1 NC	4 NC
Ground-cover index	4 Dec.	4 NC
Annual plants	2 Dec., 2 NC	1 Dec., 3 NC

1/ Inc. = Increase
Dec. = Decrease
NC = No change

Figure 4.--Watershed cover characteristics (from spring measurements) after 3, 8, and 11 years on four grazed and non-grazed watersheds.

Factor	Period	Treatment	
		Non-grazed	Grazed
Bare soil and rock	55-58	4 Dec. 1/	2 Dec., 2 NC
	55-63	4 Dec.	2 Inc., 1 Dec., 1 NC
	55-66	4 Dec.	3 Inc., 1 NC
Litter and moss	55-58	4 Inc.	2 Inc., 2 NC
	55-63	4 Inc.	3 Dec., 1 NC
	55-66	4 Inc.	3 Dec., 1 NC
Plant-density index	55-58	1 Inc., 3 NC	1 Inc., 3 NC
	55-63	4 Inc.	3 Inc., 1 NC
	55-66	3 Dec., 1 NC	1 Dec., 3 NC
Shrub-overstory	55-58	1 Inc., 3 NC	2 Inc., 2 NC
	55-63	1 Inc., 1 Dec., 2 NC	1 Inc., 2 Dec., 1 NC
	55-66	4 Dec.	4 Dec.
Ground-cover index	55-58	4 Inc.	2 Inc., 2 NC
	55-63	4 Inc.	4 Dec.
	55-66	3 Dec., 1 Inc. (x Dec. = 1.5)	4 Dec. (x Dec. = 6.5)

1/ Inc. = Increase, Dec. = Decrease, NC = No change

Figure 5.-- Comparison of 3, 8, and 11 year changes in cover on four grazed and non-grazed watersheds (from spring measurements).

Factor	Non-grazed			Grazed		
	1955 to 1958	1958 to 1963	1963 to 1966	1955 to 1958	1958 to 1963	1963 to 1966
Bare soil and rock	4 Dec. 1/	4 NC	2 Inc., 2 NC	2 Dec., 2 NC	4 NC	2 Inc., 1 Dec., 1 NC
Litter and moss	4 Inc.	4 NC	2 Inc., 1 Dec., 1 NC	2 Inc., 2 NC	4 NC	1 Inc., 2 Dec., 1 NC
Plant-density index	1 Inc., 3 NC	1 Inc., 3 NC	4 Dec.	1 Inc., 3 NC	4 NC	3 Dec., 1 NC
Shrub-overstory	1 Inc., 3 NC	4 NC	4 Dec.	2 Inc., 2 NC	4 NC	4 Dec.
Ground-cover index	4 Inc.	4 NC	4 Dec. ($\bar{x}$=3.5)	2 Inc., 2 NC	1 Dec., 3 NC	4 Dec. ($\bar{x}$=4.5)

1/ Inc. = Increase, Dec. = Decrease, NC = No change

Figure 6. -- Comparison of runoff and sediment yield from grazed and non-grazed watersheds at Badger Wash for four representative years. All values are yearly totals.

Year	Watershed pair	Grazed		Non-grazed	
		Runoff	Sediment	Runoff	Sediment
		Acre-ft./mi.			
1954	1	57.50	Not measured[1/]	50.60	Not measured
	2	59.30	Not measured	57.20	Not measured
	3	48.00	Not measured	44.60	Not measured
	4	48.60	Not measured	42.10	Not measured
1955	1	56.80	10.80	44.00	7.41
	2	64.60	14.10	51.40	15.30
	3	56.30	12.50	56.50	8.37
	4	68.60	20.40	48.40	14.70
1962	1	18.03	1.11	17.50	1.21
	2	23.04	1.14	21.01	1.30
	3	26.95	1.56	29.17	4.54
	4	14.09	0	6.32	1.47
1965	1	55.36	6.83	30.26	4.10
	2	34.66	2.24	27.20	1.90
	3	46.17	7.49	40.38	4.73
	4	66.09	7.95	46.63	6.79

1/ The sediment yield listed under 1955 was actually for the period April 1954 to July 26, 1955. This consequently was the sediment yield related to the runoff for most of 2 years, 1954-55.

The Management of Whitesage (Eurotia lanata (Pursh) Moq.) in Nevada

by
Paul T. Tueller

Whitesage or winterfat as it is sometimes called, is widely distributed throughout the western United States and Canada, ranging from Saskatchewan and Manitoba to western Nebraska, Colorado, western Texas, California and Washington. In Nevada this plant is found in all counties with the possible exception of Douglas, Ormsby and Storey. Whitesage is found at elevations ranging from 2,000 to 10,000 feet. In Nevada it is found principally at elevations between 3,900 and 6,500 feet. This is essentially a species of the lower plains and valleys where the type attains its best development. Throughout its range whitesage is found comprising a pure type in patches or alternes ranging in area from several square feet to several thousand acres (Eckert,1954). It is also found growing in association with shadscale, big sagebrush, saltsage, black sagebrush, greasewood, budsage, hopsage, Indian ricegrass, Galleta grass and some other species.

It has been estimated that the salt desert shrub range type occupies 16,863,437 acres of the State of Nevada making up about 24 percent of the state. Of this amount I have estimated that Eurotia lanata covers about 3-5% of this figure or between 500,000 and 800,000 acres. In any event, it forms or contributes to some of Nevada's best winter range.

In order to make a contribution to the proceedings of this symposium I have attempted to summarize research experience with Eurotia lanata conducted at the Nevada Agricultural Experiment Station from 1952 through 1963. During this period of time the experiment station has had a project

devoted to understanding the ecology and management of whitesage. Various experiments were conducted both in the laboratory and in the field to determine some of the following things: (1) germination percentages and seedling survival, (2) the factors influencing the establishment of whitesage in different vegetative and soil types, (3) degree of intraspecific and interspecific competition in whitesage stands (especially with Halogeton glomeratus), (4) the soil characteristics that may limit the extension of whitesage within certain habitat types, (5) the effects of insects and small mammals upon growth and establishment, (6) the forage production and establishment of whitesage on pitted range, (7) and the effects of clipping on subsequent forage and seed production, vigor and nutrient supplying power.

Most of these studies were conducted on three whitesage alternes, located in northern and eastern Nevada. One-acre, rodent-proof exclosures were established in each alterne. The Clover Valley exclosure, south of Wells, Nevada, was established in 1952. The Humboldt Valley exclosure, south of Winnemucca, and the Steptoe Valley exclosure, north of Ely, were established in 1954. The elevations are as follows: Humboldt Valley exclosure - 4,250 ft.; Clover Valley exclosure 5,700 ft.; Steptoe Valley Exclosure - 6,240 ft. The average annual precipitation at these three locations is 5.5, 9.7, and 10.5 inches, respectively.

A variety of germination rates for whitesage have been reported by a number of researchers. Some have observed quite low germination rates for this species and have also indicated poor viability with longevity. Our experiences have been excellent - most trials have given above 70%

germination and many in the high 80's and low 90's. In one lot of seeds, 88 per cent of the seeds were viable after three years of dry storage. Seed lots from different plants vary considerably (5 - 95%) even one year after collection. However, samples were very small in these instances. A vernalization treatment tends to increase germination but is not necessary.

Seed collected at Mill City and Clover Valley was compared with seed grown under irrigation at Reno. Seed grown in Reno from large vigorous plants were about twice as large as seed collected at the other two locations. Seed from Clover Valley can be described as having 27,500 seeds per pound and at Mill City 34,000 seeds per pound while the Reno grown seed produced 13,500 seeds per pound.

Results of one study conducted by Eckert (1954) showed that summer use of whitesage exceeding 20% prevented seed production. Winter clipping to as much as 95% current growth allowed, at least, some viable seed to be produced.

Seeding attempts (Eurotia lanata seeds into depleted Eurotia lanata stands) in 1955, 1957 and 1963 were all failures. In each case the establishment was less than 0.25 plants per foot of row and survival was negligible. However, the survival of some young plants indicates that whitesage will establish if it survives the seedling stage. Additional information concerning these requirements will perhaps lead to future success. Even large vigorous seeds, twice as large as any found growing in the field under natural conditions, did not seem to increase the success of seeding. Deep farrowing on, at least, one year did not add to success.

In another study by Strickler (1956) it has been shown that a beetle is active in many whitesage stands over the summer months. The beetle has been identified as a western variety of an eastern species, Aemaeodera pulchella (Hbst). Plant vigor was shown to be a factor in the susceptibility of a given plant to withstand attack. In fact, mortality was not completely attributed to insect injury. Apparently a significant relationship of total larvae and adult tunnels in the roots, defoliation, and dead plant numbers, indicate that the insect attacks low vigor plants and thereby hastens the reduction of stand vigor and density. Several other species are susceptible to this insect.

In some instances whitesage stands are kept in a depleted condition for long periods of time. In 1955, because of the danger of halogeton poisoning, sheep ranchers discontinued grazing altogether. The white-sage did not respond. At about this time rabbit populations began to build up to a peak year in 1961. During the winter of 1961-62 populations were extremely high at Clover Valley. Ronald Jensen of Wells, Nevada shipped 65,000 rabbits to Wyoming for fox feed. The spring and summer of 1962 saw a great die-off of rabbits and the following year rabbits were scarce. The Nevada Agricultural Experiment Station was urged by local ranchers to investigate this problem. Elaborate plans were made for poisoning trials, measurement of vigor reduction and other things. However, the studies were never carried out due to a lack of rabbits. We need to know a great deal more about the "10-year cycles" and in general further information about the ecology of small mammals in order to predict these events and perhaps prevent them.

A number of range pitting trials were conducted in Clover Valley in 1955, 1956 and 1957. Pits of various size and spacing were attempted (Table 1). Treatments decreased whitesage stands from 3 to 50 percent. Total production increased slightly. Soil moisture in the pitted area to 18 inches is found to be increased approximately one-third during the growing season. The protein content of whitesage when pitted was 11 percent and 9 percent when unpitted. Seed production was 10.8 and 3.8 pounds per acre on pitted and unpitted whitesage stands, respectively. Average number of halogeton plants was the same on both pitted and unpitted areas but the average weights of a halogeton plant was 10.6 and 2.3 grams, respectively (Kinsinger, 1958). However, while the best treatments increased the production, seed production, and establishment of whitesage, the results were not significant. None of these effects were lasting and the stands have by now reverted back to their pre-treatment condition. In most instances the pits have nearly filled in although they can still (spring of 1966) be seen.

Table 1. Length, depth, row spacing and pit interval for pitting trials at Clover Valley, Nevada

Length	13'	11'	3'	5'
Depth	6"	3"	3"	6"
Distance apart on contour	8'	8'	6'	6'
Distance between pits	8'	8'	2'	2'

Clipping intensities studies have been carried out at all three locations. Plots at Steptoe Valley, Clover Valley and Mill City have been clipped at various intensities during spring (April), summer (July)

and winter (December). Spring clipped plots had 25, 50 and 75 percent of the current annual growth removed; 10 and 30 percent was removed from summer-clipped plots, and 40, 60 and 80 percent removed from plots clipped in winter. Clipping intensities were estimated with some measurements made as a check. Each plot received only one seasonal clipping each year during the study. Treatments were replicated three times at each location. Plot size was 2 x 20 feet. A 1-foot buffer strip was clipped around each plot.

Twenty to 50 random measurements of current twig growth were made on each plot prior to clipping. Percent crown area (ground cover) on all plots was recorded by the area-list method (Pearse, 1935) prior to summer clipping treatments in August.

Since the different clipping treatments removed different percentages of the length of current twig growth, total production of air-dry forage by weight was determined from the clipped weight by calculating 100 percent removal of current twig growth from each plot. For example, if removing 25 percent of the current annual growth produced 100 grams of forage then, theoretically, removing all the current growth (or 100 percent) should produce 400 grams. Calculations are based on these converted production data.

Crude protein content was determined on the forage removed from the various plots in 1957 and 1958.

The production data tend to show more variation from year to year than any depletion of the stand after six or nine years of clipping.

For example, 1956 was a high production year at all locations. Clipping 80 percent of the current annual growth in mid-winter and 75 percent in the spring did not lower production appreciably. However, these clipping treatments tended to reduce vigor as expressed in height or average length of stems. Average height of plants clipped lightly at Steptoe Valley was 5-6 inches while those clipped heavily was 3-4 inches. The spreads at Mill City and Clover Valley were not so great. Plant heights were depressed from 9.6 to 8.2 and from 4.8 to 3.4, respectively.

Cover data was similar. At Steptoe Valley the heavily clipped plots had about 18 percent cover while the lighter clipped plots were well above 20 percent. At Clover Valley the greater clipping intensities had about 8 percent cover. Plots clipped lightly had over 10 percent cover. At both locations the check plots maintained the greatest cover. Summer clipping and light spring or winter use gave the highest cover values at the end of the six-year period.

Percent protein values were highest from spring clipped plots. At Steptoe Valley protein values were just above 17 percent in the spring and between 10.8 and 12.8 percent for summer and winter clipped plots. At Clover Valley spring clipped whitesage hit 13.5 percent protein while plots clipped in summer and winter averaged about 8 percent protein. These data were not gathered for a sufficiently long enough time to determine if heavy clipping reduced protein levels. The data available did not suggest that this was true.

In 1959 the study was re-designed continuing only the heavy and moderate intensity of clipping. Since 1959 plots have been clipped at 75 percent and 100 percent of use (winter plots were clipped at 80 percent instead of 75 percent). In 1960 plots clipped to 2" were added. Judging 75 percent or 80 per cent was recognized as somewhat fallacious because it tended to result in greater variability than does leaving 2-inches of current growth.

During 1956 and 1957 it was noted that halogeton plants began to appear in closely clipped plots but not in those moderately or lightly utilized. Starting in 1960 a record was kept of halogeton abundance (number of plants per plot) which occurred in each treatment plot during the year's growing period. In 1959 two additional replications of winter clipped plots were completed to determine the effect of burning off all current growth and fertilizing with 50 lb. of nitrogen.

In all instances plots with 100 percent removal of the current growth of whitesage have a greater abundance of halogeton (Table 2). The increased abundance of halogeton in these plots is apparently the result of a weakened condition of the whitesage.

Counts in 1961 at Steptoe Valley indicate that spring clipping was the most detrimental. However, in 1962 winter clipped plots have a greater abundance of halogeton at each intensity. Summer clipped plots had fewer halogeton plants in both years. Burning is apparently no more detrimental than simulated use at 100% and fertilization did not aid the closely clipped plots.

Table 2. Halogeton plants per acre (Mean of three replications).

Location, year and Season	Removal of Whitesage - Current Growth (Percent) 75% *	100%	To 2"
Steptoe Valley			
1961 - Spring	1,162	30,793	581
Summer	**	3,486	0
Winter	291	2,615	291
		8,715(burned)	
		7,553(fertilized)	
1962 - Spring	2,324	9,587	1,453
Summer	**	7,844	3, 196
Winter	6,972	24,112	4,648
		11,911(burned)	
		11,039(fertilized)	
Tobar			
1961 - Spring	1,162	30,793	581
Summer	**	31,665	291
Winter	40,670	183,304	16,849
		240,534(burned)	
		240,244(fertilized)	
1962 - Spring	27,598	682,675	39,218
Summer	**	313,740	7,263
Winter	59,553	425,583	40,670
		363,125(burned)	
		502,565(fertilized)	

*Winter plots were clipped 80% rather than 75%
**Summer plots were not clipped at 75%

The 1961 counts at Clover Valley indicate that spring and summer clipping at any level is better than winter clipping in terms of halogeton abundance. In 1962 the summer-clipped plots contained fewer halogeton plants, but spring clipping appeared to be just as detrimental as winter clipping. Numbers of halogeton plants in plots clipped at 100% are much greater than for the other two levels.

Table 3 shows the whitesage production at Steptoe Valley for the years 1960, 1961, and 1962. In the spring of 1960 the 100 percent clipping treatment was 2 or 3 times greater in yield than the 75 percent level or the 2-inch level. The same was true in 1961. However, in 1962 the increased yield of the 100 percent was less than twice as much. The same general trend takes place in the summer. There is a decrease in yield at the 100 percent level in proportion to the moderate level. However, in winter clipping after the three year period both the 80 percent level and the "to 2-inch" level produced more.

A similar trend seems to hold true at Clover Valley. These data would indicate that the first few years the 100 percent clipping treatment yields will be highest but as the vigor of the whitesage is reduced the plants are not able to produce as much and they do allow halogeton to increase.

The results to date support the idea that heavy use of whitesage increases the abundance of halogeton. Complete use of the current growth of whitesage increased halogeton while 75% to 80% use of the current growth, in spring and winter, respectively, and/or leaving 2- inches of current growth restricted its increase.

Table 3. Whitesage production at Clover Valley & Steptoe Valley

For three dates (lb./acre)
and
three levels of whitesage removal

Clover Valley			
		Spring	
Clipped Treatment	1960	1961	1962
75%	149.55	124.74	228.68
100%	226.31	145.84	265.14
to 2"	107.97	118.34	348.62
		Summer	
100%	490.62	276.83	589.13
to 2"	204.05	117.56	271.86
		Winter	
80%	133.22	162.79	237.34
100%	227.83	256.82	253.94
To 2"	138.42	136.57	186.53
100%(burned)	213.65	219.73	324.88
100%(fertilized)	216.02	266.06	408.11
Steptoe Valley			
		Spring	
75%	92.94	90.83	207.89
100%	207.12	181.66	271.22
To 2"	62.62	56.30	199.58
		Summer	
100%	440.1	307.09	336.5
To 2"	122.83	228.35	266.73
		Winter	
80%	165.31	245.31	160.55
100%	158.12	175.27	63.96
To 2"	70.74	164.07	126.30
100%(burned)	148.27	150.0	51.17
100%(fertilized)	128.25	160.24	62.35

The results obtained in several of these studies show that the invasion of whitesage by halogeton is associated with a low density of whitesage itself. Poor reproduction and a lack of vigor in whitesage has been shown to be due to at least three factors. These are (1) overgrazing by livestock and improper season of use as shown by clipping studies, (2) deficient moisture as shown by soil moisture studies and observations of disturbed areas, and (3) utilization of whitesage by rabbits (Eckert, 1954).

Overgrazing of whitesage by either stock or rabbits during the winter or spring results in low vigor as reflected by scanty regrowth. This type of regrowth is characterized by having less transpiring leaf surface than plants in moderate or good vigor. Less soil moisture is absorbed and less competition is exerted against halogeton. Late spring and summer grazing appears to be the primary factor originally responsible for opening up whitesage stands for invasion by halogeton by reducing vigor and reproduction and thereby causing a decrease in the density of the stand (Eckert, 1954).

Reduced grazing pressure involves balancing the available forage with livestock numbers, shortening the period of use, especially toward the end of the winter grazing season, and discontinuing summer use. In general, livestock numbers should be reduced or spread out in order to allow whitesage to retain its vigor. The season of use should be shortened toward the end of the season in order that whitesage can make good regrowth and produce some seed before moisture becomes limited. Although summer grazing of whitesage is limited, it should be discontinued because of its adverse effect on seed production (Eckert, 1954).

Range managers must use whitesage flats as key areas on salt desert shrub ranges and make a concerted effort to manage whitesage for maximum vigor and minimum halogeton. Kinsinger and Strickler (1961) have shown that it is not necessary for the range manager to obtain costly production data. There is a close relationship between growth and production and between ground cover and production.

A summary of research results suggests the following for the management of whitesage stands in Nevada:

1. Summer grazing is not recommended. Seed production and food storage is reduced over that of any winter grazing curtailing the reproduction and yield possibilities in the following year.

2. Moderate winter utilization levels will assure stability of forage and help to maintain the stand through greater seed production, better growth and vigor. This will allow for greater spring growth while moisture conditions are favorable.

3. In some years rabbit control programs may be necessary if stand depletion is to be prevented.

4. Grazing somewhat less than 80 percent of whitesage if utilized in winter or spring will prevent halogeton encroachment.

5. Late winter or early spring utilization can be recommended if only about 25 percent of the previous season's growth is utilized. Spring use provides forage of highest quality with respect to crude protein.

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ESTABLISHMENT AND GROWTH OF HALOPHYTES FOR GRAZING PRODUCTION FROM SALINE WASTELAND IN WESTERN AUSTRALIA

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INTRODUCTION

The nature and magnitude of the salt problem in Western Australia appears to be somewhat unique, and has necessitated a new approach to the utilization of saline areas.

Since the clearing of the natural perennial vegetation and its replacement with annual crops and pastures in the agricultural districts in south western Australia, considerable areas of land have been laid waste by salinity. The salinization has occurred under natural rainfall in districts ranging from 10-40 inches per annum and is a major problem for many farmers.

The climate in the districts concerned can be described as Mediterranean in that there is a hot, dry summer with temperatures frequently above 90°F and the winter is cool and wet with few frosts. The topography is gently undulating, having been produced over a very long time by the dissection of an undulating peneplain of 1000-1500 ft. elevation. The drainage system is extremely sluggish and in the dryer sections consists of chains of salt pans which connect and drain to the rivers only in very wet seasons.

O'Brien (1917) in discussing the salt problem stated that the annual crops used less water than the native perennials they replaced, and that the added percolation through the soil carried salts into

lower sections of the landscape where they concentrated during the hot dry summer. Wood (1924) reported increases in the salinity of many creeks and wells following clearing. He explained the phenomenon in part by suggesting that increased percolation raised the water-table which, in most instances, was already saline. The rainfall, Wood proposed, was the main source of the salts and this was subsequently supported by Teakle (1937). The composition of the salts present is closely similar to the salts in seawater. Fanning and Lyles (1964) have reported salinity of rainfall and of groundwater in Texas, decreasing with distance from the sea, and Yaalon (1963) has concluded that oceanographic airborne salts are the main source of soil salts in coastal areas of Israel. Ballantyne (1963) investigated the movement of salts from higher lands and their accumulation in lower slopes in Saskatchewan.

Teakle and Burvill (1945) and Smith (1961) have described the conditions under which salinity problems in Western Australia occur and have grouped them under the following three headings:

1. Soil types containing a high natural content of soluble salts. In particular Teakle and Burvill mention areas of low rainfall near the coast as at Salmon Gums where heavy soils are severely salt affected. In some areas, saline soils are formed on 'parna' blown from the dry beds of salt lake systems, Bettenay (1961). Mismanagement of these naturally salty soils may cause concentration of the salts in the surface and produce bare eroded patches. These soils are saline in the absence of a high water table.

2. Hillside seepage. Patches occur more frequently in the 15-40 inch rainfall districts and are due to the intersection of saline seepage waters with the soil surface on hillsides. Frequently the seepage water may be relatively fresh but concentration during summer can result in extremely high salt contents at the soil surface.

3. Watertable salinity problems occur where a change in hydrological balance has brought the saline watertable to within about six feet of the soil surface in the valley floors. Usually the watertable has 3 to 6% total soluble salts. Seasonal fluctuations of the watertable and hydraulic and salinity grades across several valleys have been reported by Smith (1962) and Bettenay, Blackmore, and Hingston (1962).

The traditional methods of saltland reclamation using soil amendments and leaching are not feasible in view of the lack of any irrigation water and the impracticability of drainage at an economic level, Stoneman (1958). Consequently, a new approach to the use of saline areas has been developed. Where mismanagement or a particularly unfavorable season has caused a deterioration in mildly salt affected land, production can sometimes be returned to normal by the use of controlled grazing and the sowing of plants such as barley, oats, and wimmera ryegrass. However, as discussed by Smith and Malcolm (1959), on more severely affected land, results with annual plants are poor and the use of special plants is indicated. Perennials dodge the annual germination hazard and in general give much more reliable production than annual plants.

Since 1953 a concentrated effort has been made to find plants and methods for restoring production from salt affected soils. The plant cover produced is used primarily for grazing by sheep. The present paper reviews the methods and plants used and discusses the problem as an example of applied ecology. The work has been done in association with Messrs. S. T. Smith and T. C. Stoneman in the West Australian Department of Agriculture.

METHODS

Initially plants have been tested in small rows, then seed multiplied for larger plantings. Since many soil types, rainfall districts, and conditions of drainage are involved, a series of over 60 field plots has been established and field plantings of likely species made. Concurrently studies in the laboratory have been used to determine germination requirements of some species and detailed field work on a limited number of sites has been aimed at specific establishment problems and determination of forage yield.

PLANTS SELECTED

From introduced and local species, a range of perennial plants has been selected which allows greatly improved production to be obtained from virtually all saline areas under discussion. The important species are:

Paspalum vaginatum is a summer growing rhizomatous perennial grass with high salt and extreme waterlogging tolerance. It is a shy seeder and must be propagated by vegetative means.

Puccinellia capillaris is a winter growing tussock forming perennial grass with high salt and waterlogging tolerance. It produces an abundance of fine seed of good viability which holds well in the head and may be mechanically harvested.

Atriplex nummularia is a summer growing upright perennial shrub with extreme salt tolerance and a good ability to survive shallow short term flooding. Seed is borne in large clusters but is often of poor viability.

Atriplex cinerea var rhagodioides is a summer growing semi-recumbent perennial shrub with extreme salt tolerance and a good ability to survive shallow short-term flooding. It produces a good crop of seed in clusters but also reproduces to some extent by stem layering.

Atriplex semibaccata is a shortlived prostrate plant with good salt tolerance. Its value is limited mainly by its tendency to fade out after a few years.

Kochia brevifolia is a summer-growing perennial shrub with high salt tolerance and an excellent ability to recover from grazing. It produces an abundance of light seed which is responsible for rapid colonization of adjacent areas. K. brevifolia will die if flooded.

Arthrocnemum halocnemoides varieties pergranulatum and ptergosperma are summer growing perennial shrubs with extreme salt and waterlogging tolerance. They produce an abundance of viable seed which may be harvested with a normal forage harvester.

The conditions to which the species are suited are given in more detail in Table 1. The judgements given are subjective to the extent that they are not supported by exact numerical data but are made by the visual assessment of many field trials. The establishment and management of these plants are discussed in several papers by Smith and Malcolm (1959), Malcolm (1961), Malcolm and Smith (1965), and Malcolm (1966).

TABLE 1. Factors affecting growth of halophytes on salt affected soils.

Hydrology	Seepage		Watertable					Dryland
Soil Surface in Summer	Wet	Moist to dry	Moist	Dry				Dry
Winter Flood.	YN	YN	YN	YN			N	N
Rainfall(ins)	10-40	10-40	15-20	10-15	15-20	20-40	12-15	12-15
Paspalum vaginatum	*							
Puccinellia capillaris		*	*	+	*	*	+	
Agropyron elognatum	+	+				+		
Arthrocnemum sp			*	*	+			
Atriplex nummularia				*			*	*
Atriplex cinerea				*			+	+
Atriplex semibaccata							+	+
Kochia brevifolia							*	*

Y = yes, N = no * = best + = also useful

YN = Yes and/or No

FACTORS INFLUENCING PLANT GROWTH ON SALINE SITES

It has become evident that a range of factors influences plant growth on saline sites. The most important will be considered in detail.

1. Salinity - The effects of salinity on normal crop plants have been discussed by many workers but studies on halophytic plants are less common. A small fertilizer study of the yield of Paspalum vaginatum on saline seepage areas indicated no response to N or P fertilizers but yield was negatively correlated ($r = 0.947$) with the NaCl content of the soil solution in summer at the time of harvest. The NaCl content of the soil solution ranged from 0.31% to 2.08% NaCl at 0-2 inches. It has been established that NaCl comprises about 75% of the total salts in these soils.

The effects of salinity on germination are important both in determining where and when the seeds will germinate. Malcolm, (1963) and (1964), has shown the effects of NaCl on germination of K. brevifolia and two varieties of A. halocnemoides. Germination of K. brevifolia was both delayed and inhibited by increasing concentrations of NaCl. When eventually after 19 days the salt solution was replaced with distilled water, a considerable amount of germination occurred. Similar results were obtained for the other species. Novikoff (1946) has reported the NaCl concentration at which 50% reduction in germination occurred for several vegetable crops. In Table 2, his figures are compared with the corresponding values for K. brevifolia and A. halocnemoides. It is interesting that extremely salt tolerant plants

such as A. halocnemoides should be so sensitive to salt at the germination stage and it is suggested that this constitutes an adaption to the hazardous saline environment. Germination can only occur after considerable leaching or perhaps in floodwaters.

TABLE 2. Salt content of medium at which 50% reduction in germination occurs.

Species	NaCl (gm/l)
Vegetable crops (Novikoff, 1946)	18-22
K. brevifolia (Malcolm, 1963)	15-20
A. haloc. var pergranulatum (Malcolm, 1964)	20
A. haloc. var pterygosperma (Malcolm, 1964)	8

2. Water Relations - Salinity and water relations are probably the two major factors determining what species will grow on any particular salt patch. Novikoff (1961) working in Tunisia, has stated that the concentration of salts and the hydrology of the site are the two major factors acting simultaneously in different degrees to characterize halophytic vegetation. He concludes that hydrology is the more important. This same conclusion has been reached by us in studies in Western Australia. (See Table 1.) Rolla and Kanodia (1962) have indicated the importance of intermittent flooding with saline water on the species growing on salt plains in Rajasthan, India.

3. Temperature - Rising temperatures appear to stimulate the growth of the summer growing perennials in the spring. But, it is not believed that temperature exercises any major ecological influence on a local scale except in the matter of germination control. Trumble (1932) showed that A. semibaccata will germinate at temperatures in the range 10-22°C with an optimum at 16°C. Malcolm (1963) found that K. brevifolia germinates over a wide range of temperatures with an optimum around 15-20°C. It would be expected that K. brevifolia would be nonspecific in its temperature requirements in view of the long period of seed production from November to July.

Arthrocnemum halocnemoides has been shown to be highly sensitive to temperature at germination, Malcolm (1964).

The interaction between temperature and salinity effects on germination is important for both K. brevifolia and A. halocnemoides (2 varieties). As salinity increases, temperatures both above and below the best range used react to give greater depression of germination.

4. Seed Factors - Beadle (1952) showed the importance of hardseededness and of NaCl in the bracteoles in preventing and retarding germination of several Australian species of Atriplex. No evidence has been found of hardseededness in K. brevifolia, but seeds of A. haloc. var. pergranulatum gave an appreciable response to scarification at all temperatures, both in the speed and the amount of germination.

It was also shown by Beadle, (1952), for five Australian Atriplex species, that if unripe Atriplex seed is picked and allowed to ripen, the resulting seed gives similar germination to that ripened on the bush.

Parallel results have been obtained by Malcolm (1963) for K. brevifolia, and Arthrocneumum spp.

Seed storage of some species is a problem. Seed of K. brevifolia deteriorates to zero germination if stored in an open container in the laboratory for a year. Malcolm (1961) found that storage over $CaCl_2$ resulted in maintenance of some viability for two years. Seed which was washed and dried prior to storage retained less viability than untreated seed, while seed from which the bracts had been removed individually was intermediate.

5. Other Factors - There is not time to discuss in detail all factors involved. Suffice it to mention that soil types, plant competition, insect attack, sowing method, and grazing management also influence establishment and growth of plants on saline soils.

ESTABLISHMENT AND MANAGEMENT

It has been found that with the exception of Paspalum vaginatum which must be vegetatively propagated, all the species discussed will establish from seed on the types of site recommended for their use. Where weed control is not necessary, as on bare saline areas, sowing may be carried out just before the opening rains in the autumn. Usually one working with a scarifier will provide a suitable seed bed under these circumstances and the seed is dropped on the surface of the ground. No conclusive evidence has been obtained for or against light covering of the seed, but all the seeds are small and must not be sown deeper than 1/2 inch.

Where natural cover such as Hordeum marinum is likely to compete with seedlings weed control is desirable and sowing must be done after the opening of the season. The best sowing time is still autumn to early winter in light rainfall districts although in some cases Puccinellia capillaris has given good results when spring sown in districts with 20-40 inch annual rainfall.

Superphosphate is usually applied as the soils are known to be deficient, although evidence has not been obtained for responses by the halophytic plants in use. Growth responses have been obtained to nitrogen fertilizer with Puccinellia capillaris and in view of the slow growth of this plant in the first year nitrogen fertilizer is often applied when sowing, especially on seed production plots.

Since all the plants under discussion make very little growth in the first winter, it is essential to give grazing protection for at least 12 months after sowing. Frequently on severe areas protection for several years is needed to allow the establishment of the initial bushes, production of seed and the growth of volunteer seedlings. Once established the plants may be grazed annually in summer and autumn in conjunction with dry annual feed.

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ECONOMIC IMPORTANCE OF SALT DESERT SHRUB

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We are all aware that there has been very little work done in the field of Range Economics as a whole and even less in the economic aspects of the Salt Desert Shrub type. Therefore, I am certainly pleased to see that a talk on economics was included on this program. It wasn't too long ago that there appeared to be an intensive jealousy, distrust, misunderstanding, or something on the part of range managers for economists, or maybe it was the other way around. At any rate the two disciplines did not seem to get along too well.

We all recognize that, although the herding of grazing animals was perhaps the third developmental level in human society, and goes back thousands of years, the application of economic principles to grazing land management has been slow to develop. Research in grazing land management has been and still is dominated by the biological sciences. Biological researchers have proven very proficient in generating data and in making management recommendations from these data. So proficient have they become that, at times, ecologically or biologically desirable has been construed to be synonymous with "good management." Seemingly, an example of this restricted thinking is an excerpt from a paper presented at the 1964 National Meeting of the American Society of Range Management by a well-known range man who shall remain anonymous. He

concluded a talk describing range research needs by saying, "We urgently need additional convincing evidence that what we call good range management pays." My reaction to this is how can there be such a thing as good management without taking into account costs and returns? It is clear in my own mind at least that this well-intentioned ecologically trained speaker had in mind something which he thought was good management and had for the moment forgotten about costs and returns.

I would be the first to admit, however, that most of the blame for the paucity of economic analyses of range problems can be placed squarely on the economist. The economist has not proven as efficient at generating data as he might have, and has often criticized the biologist for not providing him with data. Because most biological studies are not designed with the economist in mind, most grazing production data are not well suited to sophisticated economic analyses. The problem is much like the classic problem associated with industrial production data a few years back. The industrial production function, being a description of the technical conditions of production such as the technical relations between inputs and outputs of cars, or biscuits, or cans of dog food, was regarded by the economists as falling within the realm of the engineers and technologists. However, the engineers and technologists did not take responsibility for production functions either. They correctly cited that the technologist is charged with the question of what can be done, rather than what should be done.

Thus, the technologist-engineer, in the case of the industrial production functions, the technologist-biologist, in the case of grazing land data, cannot stand convicted of neglect of duty. It was not and is not the place of the biologist-technologist-engineer to supply the economist with data. This fact has not, however, prevented a barrier of misunderstanding and an air of mistrust from being perpetuated.

In industrial work the problem was solved by adequate liaison between the two groups and cooperative inter-disciplinary action. This is what is needed in range research today, i.e., more liaison and more cooperative inter-disciplinary action between economists and biological researchers.

It is a very simple matter to show that the philosophy of economics is not much different from the more traditional approaches to grazing land management. To begin with, the economist like the ecologist, agronomist, animal or recreation researcher, also studies organisms. Furthermore, just as the field of autecology "simply defined" is the study of relations between individual plant and animal organisms and their environments, the field of micro-economics, sometimes called the field of production or price economics, is the study of the mutual relations between individual economic organisms such as firms and households and their environments. Likewise, just as synecology is the study of aggregates or groups of organisms, macro-economics, sometimes referred to as national income economics, is also the study of aggregates. The concept of a species has its counterpart in an industry, and the concept of an ecosystem has its counterpart in a city, state, or nation.

Ecologists and other range land researchers and economists all use abstractions from reality or models for descriptive, predictive, and decision-making purposes. Ecologists and economists also both manipulate their respective systems attempting to achieve a dynamic equilibrium with those attributes each seems desirable. Often they may even use essentially the same models. The law of compound interest with a positive exponent, for instance, not only applies to the growth of money in a savings account, but also to individual growth of some micro-organisms and to animal populations. With a negative exponent it applies to the decay of radioactive material and to the decline of populations where the death rate is higher than the birth rate. Both ecologists and economists use regression models for estimating various relations. From this we can see that the philosophy of ecology is not much different from that of economics and researchers in the two disciplines should have no trouble working together.

In light of the similarity between autecology and micro-economics and synecology and macro-economics, I hope you can sympathize with the fact that just as an autecologist would be reluctant to talk about ecosystems or the things that fall into the realm of the synecologist, so a micro or production economist is reluctant to talk about the economics of a county, region, state or nation. Although I am a micro or production economist, since I know of no macro-economist interested in range economics, I guess I am the expert today.

One of the traditional macro approaches is to talk in terms of jobs, wages, and taxes. Not being one to break tradition, I can cite a few of these figures. Marion Clausen has estimated approximately 80,000 people are employed in all phases of range livestock and related industries in the West. The nearly 40 million acres of salt desert shrub constitute approximately 10 percent of the total range area in the west. This means there are approximately 8,000 jobs associated with this type. With a median income in the inter-mountain area of $5,000 per annum, we get a total payroll of something on the order of 40 million dollars per year. I won't even venture a guess as to the contribution to the tax rolls of the various states at this time.

Enough from the standpoint of the macro-economist. We can also look at the value of these lands in terms that the real estate appraiser would look at them. At a fee of 33 cents, the capitalized value of an AUM at 5 percent is $6.60. If the land were in the hands of private individuals and the fee were $3.00 per AUM, the capitalized value would be $60.00 per AUM. This seems to be a difference in value of more than $50.00 per AUM. Grazing permits, of course, are selling at approximately $20.00 per AUM, leaving a difference when investments in these permits are taken into account of $50.00 per AUM. Non-fee user costs of grazing such as trucking costs, herding, lower lamb and calf crops, hauling water, salting, interest on investment in the permit, usually run between $1.00 and $2.00 per AUM. $1.50 capitalized at 5 percent equals the difference of approximately $30.00. So actually,

with all costs accounted for, there tends to be little difference in the aggregate value of lands and leases based on government fees and that based on private leases.

Being a production economist, I, of course, would like to talk about the value of the salt desert shrub in these terms, but because there are very few economists trained or interested in range, there have been very few studies dealing with range problems and none that I know of, which apply to our subject matter area at this symposium.

Actually the field of economics is not a difficult one. There are only 6 main principles in economics which a person would need to know to be a good production economist. The principles are: (1) the principle of diminishing returns, and the concept of the production function; (2) the principle of fixed and variable costs; (3) the principle of optimality; (4) the principle of marginality; (5) the principle of opportunity cost; and (6) the principle of time comparisons. If you fully understand these 6 principles and the implications I venture to say that you have the tools for solving virtually any range, wildlife, watershed, or recreation management problem.

Since I cannot tell you of any instances where these principles have been applied to the salt desert shrub type, let me just briefly list some of the areas and problems where I think they might be applied. First, lets look at the grazing picture. In California I worked up some data which indicated the optimum size outfit to take advantage of economies of scale, or in more common language to get the lowest cost per dollar of output, was about 600 head of cows or about 3000

sheep. Work needs to be done on optimum size operations to be run on Federal land so that adequate operator time can be devoted to proper management.

We need to know the economies of various grazing management systems and which system gives the best return for each forage type and geographic location. We need to take a look at the economics of rates of grazing to see what is the actual optimum rate consistent with desired land management objectives. We also need to look at the economics of supplementation. Is season-long feeding better than feeding only during inclement weather and can supplementation be used with a heavy rate of grazing to give a higher total monetary return?

Also to be answered is which is the best season of use. Dr. C. Wayne Cook's information presented at this symposium indicates we can use the range twice as heavily in the winter as in the spring. The implication of this information appears clear, but it should be evaluated economically as to the alternative or opportunity cost of developing spring range areas.

In watershed work we need to know the optimum spacing of contour furrows, the optimum density of gullyplugs, and the cost involved. We need to know the reduction in runoff, and its effect on downstream siltation. We must compare the cost effectiveness of these methods of manipulation with other practices such as detention dams. We must know the increase in forage production and the extended life of storage dams to make these comparisons.

For wildlife research, we need to know what a hunter day or antelope month is worth and weigh this against other alternatives. We also must place a value on doves and chukars. For recreation, we need to know what a visitor day is worth and how many "tote-gote" days equal one AUM, and other such similar information.

In short, we need data at different rates, and/or intensities of the various alternatives that are available with the associated costs and benefits before we can adequately evaluate management alternatives. The whole thing may sound complicated, but I hope you realize that because of the PPBS dicta and LBJ's statement that we want a dollar return for every dollar spent, that problems will arise which will require more economic evaluation. As I see it, they can only be solved through cooperative inter-disciplinary effort in analyzing presently available data and in obtaining new data.

SHEEP GRAZING INTENSITY STUDIES AND VEGETATIVE CHANGES ON *ATRIPLEX NUTTALLII*[1]

by Herbert G. Fisser[2]

INTRODUCTION

The experimental pastures used in the winter sheep grazing study were established in 1956 by cooperative agreement with the Bureau of Land Management, the Bureau of Reclamation, and the Wyoming Agricultural Experiment Station. The study was initiated by the above agencies to determine the effect of different grazing intensities upon (1) spread of halogeton, (2) production of Nuttall saltbush (*Atriplex nuttallii*), and (3) sheep response measured in terms of weight change. The third objective was discarded after the 1960 study because of the greatly increased numbers of sheep needed to obtain the desired grazing intensity in a short period of time. The decreased grazing period would make any comparison of sheep weights between the different intensities meaningless.

The pastures are located approximately 15 miles northwest of Greybull, Wyoming, in an arid area dominated by saltbush. Forage production on these range lands is relatively low. The limited production per unit area, however, is offset by the vast ranges of Wyoming and other states within the intermountain area which are dominated by this

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[1]Published with the approval of the Director of the Wyoming Agricultural Experiment Station as Scientific Report Number 30.

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plant. In the Big Horn Basin of Wyoming more than 200,000 head of sheep are grazed on the salt desert shrub vegetation during fall, winter and early spring, in an area of some 5,000 square miles.

LOCATION AND CLIMATE

The Big Horn Basin is essentially surrounded by mountains -- the Absaroka Range which constitutes much of Yellowstone Park on the west, the Big Horn Mountains on the east and the Owl Creek Mountains on the south. Average elevation of the basin proper is about 4,400 feet above sea level. Winter temperatures often reach 25°F below zero and summer temperatures often exceed 100°F.

The climate is arid. Long term precipitation averages range from five to eight inches per year. Approximately 50 percent of the annual precipitation occurs as rain during the spring months of April, May, and June. September and October receive about 20 percent, mostly in the form of rain. The five winter months, from November through March, receive slightly more than 20 percent. The remaining 10 percent occurs during the summer months of July and August, usually in the form of intensive thunderstorms.

We all recognize that precipitation averages mean little when we are concerned with forage production. The only precipitation values which are relatively uniform from year to year are those which occur during the winter months from October 15 to April 15 (Table 1). These values average somewhat less than one inch for the period. During the spring growth period from April 15 to July 1, which provides approximately 50 percent of the total annual precipitation, we see an extreme amount of variation. Forage production of saltbush and associated

plants is directly related to the spring precipitation during this period. If the precipitation is low, production will be low. If it is high, production will be high. The precipitation during the summer period from July 1 to September 1, is quite variable and does little toward forage production except that less leaf shattering occurs during moist years. Fall precipitation, which also is quite variable, can do much toward keeping leaves on the plants in a moist condition. In dry years extreme shattering occurs during grazing. When a sufficient amount of moisture falls for the perennial plants to remain green, very little shatter occurs and even the annuals which normally become completely dry in July and August, will absorb sufficient moisture for utilization.

PASTURE DESIGN

The study area consisting of 640 acres, is divided into fenced pastures (Figure 1). The original modified randomized block design which was employed from 1956 through 1962, consisted of a holding pasture and two replications of pastures which were utilized at 20, 40, and 80 percent use of Nuttall saltbush. These replicated pastures were 160, 80, and 40 acres in area, respectively. Following the 1962 grazing season, it became apparent that response measured in terms in saltbush production was significantly different among the three rates of utilization. To determine more accurately the optimum rate of utilization, a new treatment was initiated. The 160 acre light use pastures were each divided into two 80 acre units. Optimum use on two of these remained at 20 percent, but was increased to 30 percent on the other two. Water for the animals was supplied in tanks located at the junction of all pastures in the center of the study unit.

GRAZING PERIOD

During the first seven years of the study, small numbers of animals were placed on the pastures for the grazing intensity study. These were weighed before and after grazing to determine influence of grazing intensity on sheep weights. The extended period of grazing necessary for this type of measurement was impractical and was discontinued after the 1962 season. Since that time, sheep have been grazed on the pastures for an average of about 20 days during the months of November and December. In 1963, instead of grazing all pastures at one time with a small number of sheep, the utilization was obtained by entering from 300 to 500 head of sheep on a pasture for a minimum of three days to obtain the necessary and specified utilization. This was done in order to have uniform utilization over the entire pasture. A smaller number of sheep such as 50 or 100 head, would not graze over the entire pasture but would tend to overgraze a small area near the center watering point and would generally follow fence lines to be near animals in adjacent pastures. Larger numbers of sheep for a few days of grazing more closely approximates the normal mode of grazing in which bands of 1,000 to 2,000 head of ewes are herded over the range land.

METHODS OF VEGETATION MEASUREMENT

Several methods of vegetation measurement have been incorporated into the study. Permanent 2' x 20' plots were located in each of the original six pastures. These were used to map individual saltbush plants. These data have been collected on an every three year basis and will be used for future evaluation of response of saltbush in terms of plant numbers and plant size to the different grazing intensities.

Accompanying 4' x 4' plots were read with a point frame. Cover of grasses and other herbaceous material were determined by recording hits from 100 points in each plot.

Annual data of vegetational cover and competition were obtained on 50' transects permanently located within each of the pastures. By use of a point frame, three hundred points were recorded on each of the ten transects in each pasture. New transect lines were established in the pastures when the fences were put in in 1963.

Erosion transects were established in 1963 and reread during the 1966 summer. These were initiated to evaluate soil movement within the pastures.

Total herbage production was determined by clipping a series of 20 plots one foot by ten foot in each of the pastures and in each of the three exclosures during mid-July. Actual utilization of saltbush is determined by clipping procedures. Immediately prior to the grazing period, ten plots, 5' x 20' in each pasture were clipped. On the basis of weights obtained from these plots the number of sheep and time required for the desired rate of utilization was determined on the basis of four lbs. of saltbush use/day/ewe. During falls of good rainfall, this figure was reduced to 3-1/2 pounds/day. Thus, knowing the acreage of each pasture, the number of days required for the desired utilization was determined. Immediately following the grazing use another series of ten plots each 5' x 20' were clipped to determine the amount of herbage remaining on the ground. During some years bad weather has forced a delay in this final clipping and in one year clipping was finally completed about mid-March.

Average numbers of halogeton plants per square foot was determined by locating from 150 to 200 plots in each of the pastures. A general increase of halogeton occurred near the center of the pasture unit which was necessarily overgrazed as in any common watering area. Abundance of halogeton and other annual weeds was directly related to intensity of use.

RESULTS AND DISCUSSION

Vegetational cover percentages of all vegetation show a common variation; increasing from 1960 through 1963 and decreasing during subsequent years (Table 2a). Climatic characteristics during 1963 were extremely favorable to all plant growth. During 1964 and 1965, precipitation values were above normal but time of rainfall created stress periods. Temperatures in 1964 were high early in the summer and limited perennial plant growth. In 1965 extremely cool temperatures during May and June also retarded growth.

Cover percentages of all forbs and grasses varied similarly to the all vegetation data except that variations resulting from differences in grazing intensity are apparent (Table 2b). The greater the rate of utilization the higher the amount of herbaceous cover. By 1964 and 1965 annual weeds had virtually been eliminated from the 20% Slight Use and the 30% Light Use pastures; and perennial grasses such as Sandberg bluegrass (*Poa secunda*), bottlebrush squirreltail (*Sitanion hystrix*), Indian ricegrass (*Oryzopsis hymenoides*), and western wheatgrass (*Agropyron smithii*) were becoming more important. On the heavier use pastures grasses were extremely sparse but annual weeds remained abundant. Whether grasses will ever replace saltbush of these rangelands

is extremely doubtful because of the arid climate and silty saline soils.

Cover percentages of saltbush, show a general pattern of increase through 1963 and decreased during later years also (Table 2c). The decrease on the lightly grazed pastures was minor. On the 40% and 80% use units a significant response to grazing intensity is apparent. Saltbush cover did not increase as much under heavy use during the favorable years as those pastures grazed lightly but decreased more during the last two years. A 25% to 35% decrease of saltbush cover is a significant change.

The composition percentages of saltbush contribution to total vegetational cover emphasizes the importance of this species on these rangelands (Table 2d). Under slight and light rates of utilization saltbush comprised approximately 90% of the composition. As should be expected, under 80% use the increased abundance of annual weeds has resulted in a much lowered saltbush composition value. Surprisingly, saltbush composition has decreased under the 40% rate of use also. During favorable years saltbush was able to increase sufficiently to restrict invasion by annuals but during years of unfavorable climatic conditions the vigor of the shrub was apparently insufficient to restrict annuals.

Production of any herbaceous material is dependent on climatic characteristics (Table 2e). Annual saltbush production averaged over all pastures was at a low of 100 lbs/A in 1960 and 1961; and increased to 360 lbs/A in 1963. During 1964 and 1965 production was reduced slightly to 330 lbs/A. Although these values follow the general trend

of total annual precipitation a closer relationship to spring precipitation can be noted at least if variations caused by other factors such as time and intensity of spring rainfall, and general temperatures are considered. Greatest production of course occurs under conditions of frequent moderate to low intensity rain storms and moderate temperatures. Extreme precipitation and temperature characteristics do not result in maximum production. Summer and fall rain storms are usually of little value for herbage production except insofar as they reduce shattering.

Saltbush production data, by rate of utilization, presents a somewhat different relationship (Table 2f). Under slight use production varied from 110 lbs/A in 1960 to 430 lbs/A in 1965. The increase from 1964 to 1965 is associated with moist conditions during September and October of the latter year which atypically resulted in pronounced regrowth prior to the November-December grazing period.

The overall average production decrease indicated in Table 2e apparently resulted from the extreme decrease which occurred on the 40 and 80% use pastures in 1964 and 1965. Saltbush plants in these pastures were much smaller and less hummocked than in the lighter use units. During years of high rainfall they were unable to effectively utilize the moisture for forage production as could the large vigorous plants in the lighter use units.

SUMMARY AND CONCLUSIONS

These data indicate a very distinct limitation to the allowable use of saltbush. Although 30% use is apparently not greatly detrimental to saltbush, 40% use results in a significant forage reduction. Use at

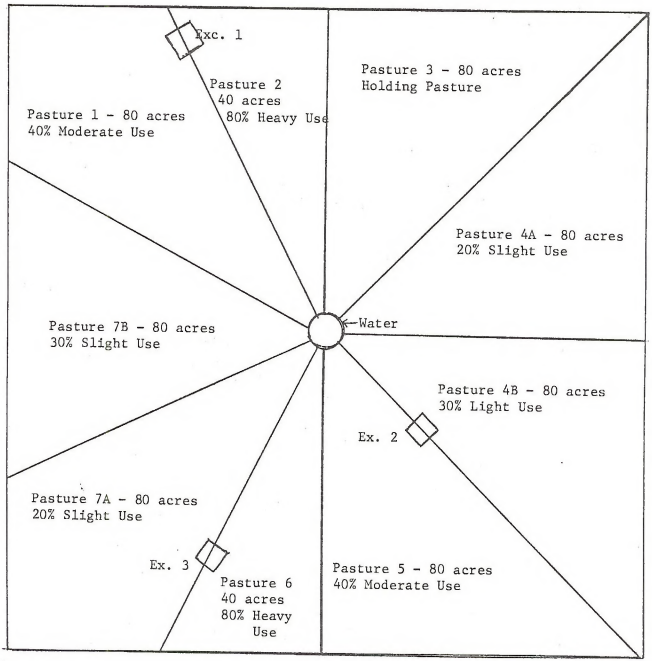
40% or an extended period of favorable moisture years would probably not deplete the vegetation too severely. Greatest indication of over-use will occur during dry years as is indicated by the 1966 data. Very little precipitation has fallen (.74" from April 15 to July 1), in fact annual weeds have failed to grow. Production has been reduced on all pastures but most significantly on the 80 and 40% use units.

The grazing study shows finally that optimum winter use of salt-bush in the Big Horn Basin of Wyoming should be set at no more than 35% of the total annual herbage production available at the time of grazing.

Table 1. Precipitation data (in inches) from University of Wyoming rain gauge, Dry Fork Grazing Intensity Pastures. 1960-65.

Precipitation Periods	1960	1961	1962	1963	1964	1965	Avg.	Percent of Total
Winter October 15 - April 15	1.00	0.87	0.81	1.34	1.09	1.36	1.08	19.2
Spring April 15 - July 1	0.60	1.35	3.01	3.78	5.59	2.31	2.77	49.2
Summer July 1 - September 1	0.72	0.11	1.35	0.21	1.15	1.90	0.91	16.2
Fall September 1-October 15	0.40	1.82	0.30	1.82	0.06	0.80	0.87	15.4
Total	2.72	4.15	5.47	7.15	7.89	6.37	5.63	100.0%
Growth Period Total (April 15 - Oct. 15)	1.72	3.28	4.66	5.81	6.80	5.01	4.55	

Figure 1. Graphical design of the Dry Fork Grazing Intensity Pastures.



Scale: 6-5/8" = 1 mile

Table 2. Vegetation, Utilization, and Precipitation characteristics measured at the Dry Fork Grazing Intensity Pastures, 1960-65.

2a. Cover % - All Vegetation

Year	20% Use	30% Use	40% Use	80% Use
1960	20	--	14	14
1962	21	--	19	25
1963	25	29	26	26
1964	19	17	14	15
1965	15	17	14	13

2b. Cover % - All Forbs & Grasses

Year	20% Use	30% Use	40% Use	80% Use
1960	7	--	1	4
1962	7	--	4	13
1963	10	12	12	14
1964	2	2	3	5
1965	1	2	3	4

2c. Cover % - Saltbush

Year	20% Use	30% Use	40% Use	80% Use
1960	13	--	13	10
1962	14	--	15	12
1963	15	17	14	12
1964	17	15	11	10
1965	14	15	11	9

2d. Composition % - Saltbush

Year	20% Use	30% Use	40% Use	80% Use
1963	90	92	86	73
1964	90	90	80	72
1965	89	91	78	69

2e. Precipitation - Saltbush Prod.

Year	Ann. Prec. (In.)	Prod. lbs/A	Spring Prec. (In.)
1960	2.7	100	0.6
1961	4.2	100	1.4
1962	5.5	240	3.0
1963	7.2	360	3.8
1964	7.9	330	5.6
1965	5.6	330	2.3

2f. Use - Saltbush Production

Year	20% Use	30% Use	40% Use	80% Use
1960	110	---	110	70
1961	140	---	110	60
1962	290	---	240	200
1963	390	370	350	330
1964	390	350	300	270
1965	430	430	260	180

RESEARCH NEEDS AND BASIC MANAGEMENT CONSIDERATIONS ON SALT-DESERT SHRUB RANGES

Selar S. Hutchings[1/]

INTRODUCTION

The symposium during the past few days and the trip to the Desert Experimental Range have outlined, in general, our present knowledge and research studies on the salt desert. We are aware of the expanse and location of the salt-desert vegetation. We have made preliminary studies on the plant-soil relationship; we know something about the palatability and nutritional quality of the plants; and we have seen some of the results of grazing management. From past studies we have become keenly aware of the potentials of the salt-desert vegetation to furnish forage for livestock and game. We are also aware of the aesthetic values to the casual tourist. As we step back and appraise our research accomplishments, we find we have made notable progress. However, in spite of our progress, we have only scratched the surface.

We need to know a lot more about the physical and biological relationships which operate within the salt-desert shrub communities before we can manage them intelligently. Some of the factors we are interested in are discussed below, but they are not necessarily listed in their order of importance.

1/ Principal Plant Ecologist, Intermountain Forest and Range Experiment Station, U.S. Forest Service, Ogden, Utah. Presented at the Salt Desert Shrub Symposium at Cedar City, Utah, August 1-4, 1966, sponsored by the Bureau of Land Management.

GRAZING

Livestock grazing is probably the most important use of the vast areas of salt-desert vegetation. Past and present grazing studies have given us general information on the effect of season and intensity of use, particularly during fall, winter and early spring periods. We also have general information on palatability and nutritional quality of the forage species. Again, this is confined primarily to the winter grazing period. Grazing on many salt-desert areas, particularly those used by cattle, is not confined to the winter period but extends into spring and summer.

Essentially no studies have been made of palatability, nutritional value, or grazing effects of spring and summer grazing on salt-desert vegetation. To supply needed information for sound management, grazing studies should cover the following:

Season of grazing

Systems of grazing

Sheep versus cattle grazing

Forage utilization and nutrition

Distribution--Fenced range units

Introduced weed pests

Revegetation

Cultural practices--Water control measures

Season of Grazing

Most of the grazing on the salt-desert shrub ranges is in the winter period, October to May. This has been done by long tradition and custom, because water was not available on many of the areas. Consequently, grazing was confined to periods when snow was available to the livestock. Recent development of water and popularity of hauling water have greatly extended the grazing use of salt-desert areas. With extended grazing seasons, we need to know the effects and required stocking rates for early fall grazing, late spring grazing, and summer grazing. We also need information on nutritional value and palatability of the individual forage species for all seasons of the year.

Systems of Grazing

Little information is available on systems of grazing for salt-desert vegetation. Studies at the Desert Experimental Range provide information on individual seasonal periods, on some two-period rotational tests, and on one or two units of alternate-year grazing. From previous studies, we know that the relative utilization of species varies with the period of use. For example, bud sagebrush is a choice plant for sheep during the early spring, and it receives heavy use during this period under all rates of stocking. The greatest improvement in bud sagebrush has been obtained under fall or midwinter grazing. Some improvement was obtained by rotational midwinter and early spring grazing. Alternate-year grazing probably offers some advantages over

rotational grazing treatments. Under alternate-year grazing, stocking rates can be relatively heavy during the year in which grazing treatments are applied. The added grazing pressure provides more uniform distribution of livestock and also more uniform utilization of the forage species. At the Desert Experimental Range, vegetation made remarkable improvement on a range unit grazed in midwinter in alternate years. Winterfat, bud sagebrush, black sagebrush, Indian ricegrass and needlegrass--all good forage species--were improved and maintained in vigorous condition, and now make up most of the plant cover. Under alternate-year late-winter grazing, winterfat made remarkable improvement, but bud sagebrush was injured.

Additional studies are needed to evaluate various other rotational systems, rest rotation combinations, alternate-year grazing, and seasonal rotational grazing within years--such as once or twice-over grazing. These rotational systems should be evaluated for both vegetation and animal response.

Cattle versus Sheep

To date, grazing studies have been confined to either sheep or cattle. Most of the salt-desert shrub areas are better adapted to sheep than to cattle. Sheep grazing is much more uniform than cattle grazing, especially on mountainous areas; also, sheep utilize many more species, especially shrubs, than do cattle. Therefore, the desert-shrub ranges have a much higher utility for sheep than cattle. Some forage species such as winterfat and Indian ricegrass are used by both sheep and cattle. However, in general, sheep make more use of the shrubs than cattle, and cattle utilize the grasses in preference to shrubs. General observations indicate that shrubs deteriorate under sheep grazing and that grasses decrease under cattle grazing.

Studies are needed to determine (1) the grazing capacity and relative value of ranges for sheep or cattle, (2) successional trends under sheep or cattle grazing, (3) rotational grazing systems for alternate sheep and cattle use and common use.

Forage Utilization and Nutrition

Previous studies have indicated the relative palatability and nutritional quality of some of the major forage species of the salt-desert shrub vegetation. Such studies have been made primarily during the winter grazing season. In good forage years, salt-desert shrub ranges provide good maintenance rations for both cattle and sheep. However, in drought years or during heavy snowfall periods, grazing animals frequently are inadequately nourished, particularly during the late winter grazing period which coincides with late pregnancy stages in both sheep and cattle. More studies are needed on supplemental feeding or systems of grazing to maintain suitable levels of nutrition. In some places, supplementing cattle with a mixture of salt and meal has been done successfully, especially on range where good distribution is obtained by water hauling. No effective way has been developed for supplementing sheep. Feeding pellets or corn on the ground, or salt and meal in bunks on bedding grounds, results in excessive trampling. Also, sheep often pick up large quantities of dirt.

A basic study of palatability and nutritive value of plants is needed to answer the following questions:

1. What makes a plant palatable?
2. Why are some species more palatable than others?
3. Why are some plants of a given species eaten, while others are left untouched?
4. Why is palatability so variable from year to year?
5. Is palatability related to chemical composition, stage of growth, genetic strain, succulency, or phenological stage of plant growth at which frost occurs in the fall?
6. Can these characteristics be modified by plant selection and plant breeding or by providing soil amendments?

Distribution--Fenced Range Units

During the development of the grazing industry of the West, livestock, especially sheep, were grazed across the open range. Recently, private allotments have been and are being assigned. Many of these, especially on cattle ranges, are being fenced to control the animals. With the establishment of private allotments and fenced units, distribution becomes a management problem on individual allotments.

Distribution of cattle on allotments is usually very unequal. Cattle tend to concentrate around water and primarily on the gentle terrain. Since permanent watering places are widely scattered, areas around water are heavily overgrazed, while remote areas are left almost untouched. A few cattle outfits haul water to obtain good distribution. After one area is grazed, troughs are moved to a new location. With this procedure, rotational or deferred systems of grazing can be applied.

Studies are needed to determine size of grazing units, use of permanent versus temporary watering places, frequency and distribution of water, and fence requirements.

Each year the trend from sheep to cattle becomes more pronounced. This results in incomplete harvest of the forage crop because cattle do not make as full use of the forage as do sheep. Undoubtedly, transfers from sheep to cattle are related to many factors. Probably the major cause is the inability to hire reliable herders. If labor problems continue, sheepmen may be forced to graze their sheep on fenced ranges without herders. In fact, a few are already doing it. Many questions need to be answered before effective management can be applied to sheep grazing on fenced range. Some of these are as follows:

1. What size units and how many sheep per unit would be desirable?
2. How can we get uniform distribution and grazing?
3. What are the water requirements--amount and distribution?
4. Hauling water versus development of permanent watering places?

5. How often should watering places be moved?

6. How can predators be controlled effectively?

7. What type of fences are needed?

Introduced Weed Pests

Introduced annual weeds cover vast areas in the salt-desert shrub vegetation. The most noticeable of these are Russian-thistle, poisonous halogeton, and cheatgrass. These weed pests occupy disturbed and overgrazed ranges and rapidly deplete soil moisture during the early spring, depriving native forage plants of needed moisture.

The introduced annuals fluctuate widely from year to year, depending on seasonal precipitation. In favorable years there are lush stands of halogeton and Russian-thistle; but in dry years, stands are sparse and plants short or absent. Halogeton appears to grow more luxuriantly in valley bottoms than on the upper alluvial fans. Undoubtedly, halogeton and other annuals are here to stay, and we must learn to manage ranges to control them. Therefore, studies are needed to determine (1) ecological requirements for halogeton and other annuals, (2) relation of annuals to establishment and growth of perennial species, and (3) moisture requirements and use by halogeton and other annual species.

Revegetation

Many areas within the salt-desert zone need to be revegetated to provide forage for livestock and adequate soil cover. Although most seeding trials have been unsuccessful in the past, we need more studies to determine how, when, and what to seed. More emphasis should be placed on native species, especially shrubs. New techniques of soil pitting, applications of mulch, and other cultural practices may provide a suitable habitat for seedling establishment.

Approximately 10 to 20 percent of the salt desert lies in low valley bottoms dominated by greasewood, with little or no other vegetation. Other areas are dominated by low-quality or unpalatable vegetation. I believe many of these areas can be improved if we direct research to the problem of seeding and rehabilitation of the harsh, dry sites in the salt-desert regions.

Plant breeding and selection are fundamental in achieving fullest forage production. Wide variations occur between strains of species adapted for range seeding. Strains of some species have been found to vary almost as widely in important attributes as entirely different species. Some strains are many times more productive than other strains. It is important that good varieties be selected and developed.

Cultural Practices--Water Control Measures

Much of the summer precipitation, which comes in torrential downpours, is lost in runoff. Studies should be made to find ways of conserving the precipitation and getting it into the ground. Some trials have been made with water spreading, pitting, and contour furrows. More effort should be directed toward soil-moisture studies.

WEATHER

Weather is the overriding influence in the growth process of plants. Our present information about weather is meager. At Delta, the Desert Station, and Modena, we have long-time records of temperature and precipitation. These stations, plus others around the fringes of the salt desert, furnish us with general concepts of average annual precipitation and temperature and some idea regarding annual fluctuations in these factors. However, we know little or nothing about wind, evaporation, and character or distribution of winter and summer storms.

Much of the salt-desert empire in western Utah and Nevada lies in a zone between or on the border of northern and southern cyclonic storms. Some authorities draw the line between these cyclonic storm areas at Reno and Ely, Nevada and Delta and Green River, Utah. During summer periods, some storms that cover the salt-desert areas originate in the Gulf of Mexico. If such storms are large and extensive, they reach well into Nevada and Utah. What influence do storms from these three sources have on the salt-desert vegetation? How often do they occur? Can they be forecast? General observations tell us that winter storms are orologically influenced, while spring and summer storms which sweep across the desert areas, dropping torrential downpours, essentially are unaffected by topography.

AUTECOLOGY OF PLANT SPECIES

A few plant species (shadscale, winterfat, and bud sagebrush) have been studied quite intensively, at least on some aspects, primarily for palatability, nutritional qualities, and growth. But we need additional information on distribution, growth requirements, relationship to weather, seed production, reproduction, longevity, and soil-plant relationships.

In addition to the above species, there are numerous others that have been largely ignored: small rabbitbrush, threeawn, galleta, sand dropseed, fourwing and Gardner saltbush, globemallow, Mormon tea, black sagebrush, dwarf sagebrush, greasewood, saltgrass, etc.

SYNECOLOGY OR POPULATION DYNAMICS

Within the salt desert, many plant communities are composed of relatively few species. These species tend to grow in microenvironments which are favorable to their growth and reproduction. Within the salt desert these microenvironments are often controlled by soil characteristics--primarily the amount and kind of soil salts and soil moisture. Although many individuals have made some soil-plant studies, we still know little about desert soils or about soil-plant relationship. We need answers to the following questions: What are the limiting environmental factors for the various plant communities? What are the major plant communities, their extent and distribution? What are the population dynamics associated with changes in weather? How can effects of weather and grazing be separated?

Numerous plant communities exist, affected by elevation, precipitation, soil characteristics, soil parent material, regional distribution, etc.; hence synecological studies are almost limitless. Drought and insect epidemics are often catastrophic, resulting in heavy plant mortality. When such losses occur, we need to know how to adjust management so we can take advantage of these natural phenomena to improve forage quality.

INSECTS AND DISEASE

The magnitude of insect damage and the influence of pathological diseases are almost a complete blank as far as salt-desert vegetation is concerned. Cursory collections have been made by entomologists and pathologists, but range technicians and management personnel have generally ignored these two aspects of environment. Plant mortality has been regarded as a natural phenomenon, or in most cases has been attributed to grazing damage.

Insect and disease damage has been observed on many plants. Tent caterpillar causes severe damage to bitterbrush, chokecherry, and desert almond. Recently, heavy caterpillar infestations have occurred on desert almond, and heavy mortality of serviceberry has been caused by rust infestation. Large areas of sagebrush have been killed by Aroga websteri and Tortrix moth. About 1959, sawfly infestations on pinyon pine nearly ruined the Christmas tree industry in Nevada, and between 1958 and 1961, the tussock moth caused heavy damage to bitterbrush near Reno and Ely. Anacamptodes species have been recorded on mountain-mahogany in Owyhee County in Idaho.

The most recent insect infestation affecting range plants is the grass bug, Labops hesperius, which has infested thousands of acres of crested wheatgrass.

Most of the insect and disease damage listed above is not on salt-desert vegetation, but it illustrates the potential hazard of insects and disease.

Ants are one of the common insects in the desert areas. On some ranges, ant infestations are conspicuous because of large bare areas around the anthills. However, much of the insect and disease damage goes unnoticed until populations reach epidemic proportions.

Studies are needed to determine the insects and disease associated with salt-desert vegetation. How numerous are insects, and how widespread is disease? How much damage do insects do? Are insects beneficial? Can insects and disease be used to manipulate plant populations by destroying undesirable plant species?

RODENTS AND RABBITS

Rabbits, kangaroo rats, pocket gophers, and mice are known to be present in varying populations on the desert. Fautin, in his study of salt desert, described several biomes, listing the plants and animals in each. A few studies have been made of the small mammal population of the desert, but they have been limited in scope and confined to a few localities. Small mammal populations fluctuate widely from year to year, following cyclic trends. In some instances, rabbit populations have been so great they caused excessive damage to grass and, in a few instances, to winterfat.

Unless the populations become excessive, the influence of rodents has been ignored. Kangaroo rats and pocket gophers have caused mottling in desert vegetation by destroying some species. For example, in mixed winterfat and rabbitbrush, large "bare inslands" or "islands of winterfat" around rodent mounds stand out in contrast with surrounding black sagebrush and rabbitbrush because of modified soil characteristics or selective damage to vegetation by kangaroo rats.

We need information on rodent populations and how they fluctuate. We need to know both the harmful and beneficial aspects of rodent activity. And lastly, we should know when, whether, and how to control the populations.

I wrote this part of my paper during a field trip to the Sawtooth National Forest. While writing, I noticed two gray squirrels and many chipmunks scampering through the lodgepole and aspen forest. Occasionally, the two gray squirrels would romp into the openings, stand on their back legs, pull the tall grass stems over with their front feet, and eat the grass seed. This procedure was followed time and time again. After watching them intently for several moments, I walked over to examine the effects of their activity. The squirrels had carefully removed the ripened seeds from the seedheads, but had not broken or cut the grass stems. Such rodent activity could easily be overlooked.

WILDLIFE

Only a few studies have been made on the wildlife of the salt-desert vegetation. Where do antelope, rabbits, coyotes, bobcats, lion, swift fox, and badger fit into the ecology of the salt desert? What about the bird life: mourning doves, eagles, hawks, falcons, ravens, and the smaller birds? Research in these fields is wide open. Can wildlife be increased to provide hunting and recreation? Where do wild horses fit into the salt-desert ecology? Are they a wildlife species to be hunted and captured, or should they be considered only from their recreational and aesthetic value? How can they be controlled and managed?

Undoubtedly, water is a limiting factor in the distribution and abundance of wildlife. Therefore, we should study ways of developing seeps, springs, and ponds for wildlife use. We need to know how livestock use of water affects wildlife. It may be desirable to develop water for exclusive use of wildlife. We should also determine habitat requirements for all the desert fauna.

RECREATION

Recreation in the salt-desert zone is untouched. A few years ago, travel to the salt-desert areas was almost unknown. Now, with modern camping equipment and a network of paved and dirt roads, thousands of people tour the "desert" areas. What lures people to these dry expanses? Is it isolation? distant vistas of the mountain ranges? rock hunting? the rugged geological formation? or merely a yen for exploration?

Research in the recreation field is needed to answer many questions:

a. What is the future for recreation in the salt desert?

b. What camping facilities are desirable and needed?

c. How can recreation be correlated with other uses of the salt desert?

ROADS

Roads across the salt-desert areas are becoming more numerous every day. Land management agencies, livestock operators, prospectors, mine owners, and others promiscuously build "roads" or trails to reach specific areas. Careless location of roads and low road standards result in excessive vegetation removal and heavy erosion. The destructive effects of road building are expanded manyfold by promiscuous truck and jeep travel.

Many roads are constructed with bulldozer and grader in a single trip, leaving heavy ridges of dirt along both sides, which creates a "ditch." Some of these roads are not maintained; others receive only minor maintenance which consists of a once-over trip with a grader. This increases the mounds of dirt along the roadside and keeps the water on the roadbed, where runoff causes heavy erosion. Much of the damage from roadbuilding can be controlled by administrative directives. However, some research is needed to evaluate road design and road maintenance procedures to assure adequate drainage and a minimum of erosion hazard.

SUMMARY

In summary, there are vast opportunities for research in the salt-desert shrub zone, especially if the concept of multiple use is applied.

At present, range management is the predominant activity on these lands; consequently most research studies should be on the management and improvement of the ranges for livestock grazing. However, research activities should recognize other uses and be flexible enough to change with economic and social pressures.

LIVESTOCK MANAGEMENT ON SALT DESERT SHRUB RANGE

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I. Introduction:

Historically, desert shrub range was first used by cattle and later by sheep. The grazing value of this type was not initially realized and it was overlooked by trail herd scouts. Following severe cattle losses in 1885-86, stockmen changed to sheep raising and found the salt desert shrub area to be ideal winter range.

Salt desert shrub range was the base upon which Utah became a major sheep producing state.

An increase in cattle numbers occurred during the 1940's and 1950's but the current trend is again toward use of the salt desert shrub type for winter sheep range.

II. Present day operations:

A. Sheep

Bands characteristically move onto the desert for winter grazing about the first of November. Past practice has been to remain until mid-April or the first of May. Presently, bands tend to leave for spring range earlier - About April 1.

The typical winter range herd varies between 2000 to 3000 head of ewes per band. A band is usually split into two herds for the summer season. Following grazing on spring, summer, and fall ranges, sheep return to the desert for the winter period.

1. Breeding

Throughout most of the west the white-face range ewe is favored over black-face breeds. Better Utah herds are predominately Rambouillet ewes, though this breed is sometimes mixed with Correidale.

Many Utah sheepmen use black-face Suffolk or Hampshire rams or Suffolk-Hampshire crosses. Black-face rams on white-face ewes produce all black-face lambs which are excellent feeders and are preferred by feeder buyers.

A few sheepmen still use Rambouillet rams, in part, to obtain white-face lambs for breeding herd replacements. However, the most popular practice is to purchase replacement lambs from northern Wyoming or Montana.

Some operators do not cull their ewes for fleece weight or grade of wool. However, it is not unusual for their sheep to average 11½ to 12 pounds of wool with a 60 to 61 percent shrinkage. Very often the clip is sold for top price not graded.

Bucking begins in early December, with lambing occurring in April and early May. There is a trend toward earlier lambing. This means removing lambs from summer range at an earlier date and possible marketing at a more favorable price.

2. Feeding

Sheep grazing salt desert shrub ranges generally do not take salt. This makes feeding of needed phosphorus difficult, and it is necessary to use concentrates containing attractant feeds

such as cottonseed meal fortified with 20% dicalcium phosphate.

During the harshest winter period, beginning about the first of January, sheep are fed cottonseed cake at a rate of 1/4 to 1/3 pound per head per day.

3. Disease Control

Ranchers have indicated that trouble with "stiff lamb disease" can be eliminated with a good supplementation program.

The principal health problem is poisonous range plants. "Bighead" appears to be less a problem than it was several years ago. Locoism has occurred intermittently over a period of the last 10 years. There is a need for research on the loco problem - how it effects the animal and what treatment is required.

Halogeton kills about 1/2 of 1 percent of the average herd. According to sheepmen, hungry animals and short range are the principal causes of loss.

B. Cattle

There is wide variation in the season of use of salt desert shrub ranges by cattle. Some graze in winter only; others the year around. There are also differences of opinion between stockmen as to whether desert range has the greatest utility for cattle or for sheep grazing.

Ranch units grazing the desert year around haul their livestock to better feed only during extreme drought conditions.

Those grazing only during winter attempt to move to their spring range in the foothills prior to calving, or about mid-March.

Approximately the same schedule of spring, summer, and fall range use as practiced by sheepmen is followed by cattlemen. The principal variation is the time of leaving summer range. Removal date for cattle is variable, depending upon the kind of season (the amount of precipitation).

1. Breeding

Most cattle are Hereford. Improvement is attempted through bull grading. Under current systems only bulls grading "B" or "past" are permitted to run on the range in common with other users.

2. Feeding

Cottonseed cake, plus salt - phosphorus mixtures are the common supplements fed on salt desert shrub ranges. Some cattlemen feed hay during periods of deep snow.

3. Diseases

Venereal diseases have been the greatest disease problem of cattle on desert ranges. Artificial insemination is being used to combat this problem.

In contrast to "shortgrass" and "midgrass" winter ranges for cattle, there is a striking absence of urolithiasis among cattle grazing desert ranges.

III. New Approaches

A. Sheep

The greatest single need is for a wool improvement program. Increasingly, sheepmen are weighing the clip and culling ewes on the basis of weight and grade of the wool, and the number of lambs produced.

Sheepmen acknowledge the importance of flushing ewes just prior to breeding time to improve lamb crop percentage. There is more use of supplements. This is with phosphorus and protein where grass is lacking, and with energy feeds where the predominant browse is big sagebrush.

B. Cattle

There is greater inclination toward breeding selections based on market needs. This is with the use of modern improvement methods, including selection on the basis of weight for age, efficiency of gains, carcass quality, and yield of high-value cuts.

SALT-DESERT SHRUB RANGE SYMPOSIUM SUMMARY

The first question asked was "What is the salt-desert shrub type?" This is generally considered a vegetative type with varying tolerances to a rather high content of the salt in soils having developed under low rainfall regimes. The type is a division of the northern desert shrub formation where perennial chenopods dominate.

The most important factors affecting distribution of salt desert shrub communities are perhaps: 1. soil moisture relations and, 2. salt concentrations in the soil.

It was suggested that total soil moisture stress indexes for various plant expressions would characterize certain plant communities of the salt desert shrub type.

Salt tolerance to the extent that roots are able to penetrate layers of salt concentration and the fact that certain species are able to germinate and establish seedlings in soils of high salt content make most of the component species true halophytes.

General climate is important in the development of salt desert shrub communities. The environment in which they occur is characterized chiefly by low precipitation and high temperatures. Low precipitation and poor drainage cause salt accumulation at shallow depths in the soil. Salts in the soil are important in hydrological aspects of soil as they relate certain physical properties of the soil. The structure of these soils affect absorption and infiltration. Toxicity effects of salt may also be a factor in ionic exchange and mineral metabolism.

Time is important in determining the geomorphology of the desert areas. Most salt desert shrub areas are rather old in origin but some are rather recent.

Salt desert shrub types in some areas are substantial contributors of water and sediment to river drainages.

Surface runoff detracts from the moisture available for plants but contributes to water yield. Amount of surface runoff also affects the loss of soil, organic matter and fertility. Heavy losses occur from the steeper topography and is deposited on the basins or lower lands.

Cover of vegetation affects the loss of soil and water from an area. Vegetation affects velocity of water movement and also affects soil structure and infiltration of water. As velocity and quantity of water increases, heavier loads are carried and the runoff becomes more abrasive.

Man-made structures can supplement nature's means of controlling erosion. Dams, pits, gully plugs, and other artificial impediments can act as water conserving measures as well as controlling erosion. In addition these structures reduce the velocity and sedimentary loads. If we understand the role that natural forces play, we can effectively supplement nature in management of ranges and watersheds.

Gully plugs and contour furrows collect water and subtract from the total water yield. Yet the quantity of silt which reaches the main channels is reduced. Silt laden waters shorten the life of the large water storage projects on the main river drainages. Gully plugs and furrows also produce additional forage as well as vegetational cover.

Results indicate that well-designed man-made structures effectively utilize the precipitation for vegetation growth and erosion control. This could conceivably be an improvement over what could be expected of nature, even over geologic time in the control of erosion and runoff.

It was pointed out that annual summer forage utilization was more harmful to salt-desert species than annual late spring, and annual late spring harvesting was more detrimental than annual winter use. Alternate late spring use appears to be the only solution to late spring and summer use of desert ranges. The effect of intensity of use is more marked during annual late spring and summer harvesting than fall and winter harvesting.

Salt-desert shrub ranges, like other range types, produce a higher nutrient level during spring growth until dormancy is reached sometime during mid summer or fall. The nutrients during spring area adequate to meet the requirements for growth and lactation of range livestock. However, it must be remembered that plants during this period will tolerate only light use and thus approximately one-half the grazing capacity must be sacrificed in order to obtain this higher nutrient level.

Studies on foothill ranges of the intermountain area suggest that more adequate spring ranges can be developed from seeding introduced grasses. This would relieve spring and summer grazing on desert ranges and allow the maintenance of larger and more stable livestock numbers.

It was stated that antelope was the only big game animal that used the salt-desert shrub range type extensively. These herds do not seem

to reproduce well and are just maintaining their numbers. Predators and poor range condition are believed responsible for the poor response of antelope on salt-desert shrub ranges. Antelope seem to prefer big and black sage to all other desert species. However, they use most species slightly, at least during some period of the year. It may well be that the salt-desert shrub type is not suited to antelope grazing and was never really their native habitat.

In local areas some deer herds use the fringes of the salt-desert shrub type during severe winters. Several game bird species such as chukars and mourning doves use the intermediate areas between the foothill and desert types.

Rabbits are becoming a game animal and the desert types support large numbers of these species.

Development of water through catchment basins or precipitation catching aprons have made it possible to increase wildlife populations in many salt desert areas.

Where annual precipitation is less than 10 inches, the possibility of successful rehabilitation through seeding is tenuous. It was stated that perhaps 1,000 plantings with 200 species or selections have been made on desert areas. Less than one percent of these seedings have been successful.

New plantings should consider selection of native species and their natural hybrids and ecotypes that appear adapted for seeding desert areas. New introductions and new selections that produce large quantities of viable seed are needed. New selections are needed that have a high tolerance for salt and arid conditions. It appears that

desert shrubs have greater promise for artificial rehabilitation than desert grasses at the present.

Range livestock nutrition is extremely important to both the producers and the managing agencies. Research in the field of range nutrition has been hampered because of the slow process of developing and testing methods and techniques.

Reproductive rates of cattle on some salt desert shrub ranges may be as low as a 30 percent calf crop but perhaps average 50 percent where cattle run yearlong on the desert ranges. It is believed that weaning weights of calves are about 100 to 50 pounds less than farmstead produced calves.

Salt-desert browse is relatively high in protein, phosphorus and Vitamin A, whereas grasses are relatively high in energy on desert ranges used for winter grazing.

Supplements should be scattered out or else range deterioration will result from concentration of animals.

No benefit from phosphorus supplement among mature cows on salt-desert range has been realized but 8 grams of phosphorus per day gave increased gain among calves.

When cattle change from grass to browse because of the scarcity of grass on winter ranges, weight losses occur. This may be a result of reduced daily intake or nutrient deficiencies in the plants. In general, browse species of salt-desert shrub ranges meet the range standards for protein for livestock during gestation. However, they may be slightly deficient in phosphorus and decidedly low in energy-

furnishing constituents. Grasses associated with browse species of the salt-desert shrub types are markedly deficient in protein, phosphorus and carotene but are good sources of energy. Browse are comparatively high in carotene and if as much as 15 percent shrubs is included in the diet during the winter there should be no Vitamin A deficiency.

A variety of vegetation conservatively grazed reduces the need for supplements on salt-desert ranges. Overgrazing may result in a need for a greater quantity or even a more expensive supplement over a longer period of time since intensity of grazing reduces daily dry matter intake and digestibility of ingested material.

Analyses of physical and chemical properties of soil has not explained the sharp ecotones displayed by various plant communities in the salt-desert shrub types of the Great Basin. However, salt-desert shrub communities of the upper Colorado Plateau were distinctly related to differences in soil texture, structure, and chemistry.

It appears that most ecological studies in the salt deserts have been fragmentary, having neglected many aspects of the ecosystem. These include soil-plant relationships, microclimates, pathology of plants and animals, and the influence of insects.

Studies, in many cases, should consider the complete ecosystem and not certain aspects that appear of interest to the investigator. Better studies will require a team approach. A full and complete understanding of salt desert ecology will not be attained until this approach is initiated.

It was pointed out that application of results should not be inferred until economic justification has been studied. Application of ecological principles is one consideration but application of economic principles is another. Thus the economic aspects should be considered in management and improvement ventures on salt-desert shrub ranges.

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